THE TEMPORAL LIMITS OF TECHNOLOGICAL ADVANTAGE

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DISCLAIMER

The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, Department of Defense, the United States Air Force, or Air University.

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ABSTRACT

This study analyzes the temporal limits of advantages gained by states seeking to achieve a technological edge over their competitors. It seeks to approach an empirical answer to the length of the advantage and the conditions that limit that duration. The study analyzes three different technological developments of the twentieth century: early-warning radar, atomic weapons, and stealth technology. In each case, it compares four variables: political context, scientific/industrial base/resource capacity, security, and systemic integration. Those four variables provide a baseline for understanding how the conditions shift to allow for longer-duration, as in the stealth case, or shorter-duration, as in the early-warning radar case, advantages. The object of the study is to provide a firm analysis of the variables that define the conditions that will inform future investments in technological advantage. This is especially important in the second decade of the twenty-first century, as the US invests in a so-called "third-offset strategy" that will likely consume a good portion of available military spending. By demonstrating the conditions that allowed for significant duration advantages in the past, this study can inform the future decision-making processes and allow for more prudent decisions.

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Chapter 1

Introduction

Since the beginning of history, adversaries have sought a competitive advantage. As espoused in the realist tradition of international relations, any advantage, no matter how small, is consistently sought in order to provide leverage that can be used to adjust the balance of power in one side's favor. The perception of power allows for the people of a given state to achieve a sense of security – they no longer have to fear danger from the actions of another state. This increases a state's legitimacy and therefore strengthens the state both domestically and internationally.

Technology provides a key component on the way to achieving this advantage. In many cases, technology can be the end to itself. If one country possesses a technological capability that others do not, it gains a competitive advantage by increasing its relative power over the other(s). In turn, this advantage usually causes the other powers to respond, either by trying to match the technological development or by accepting the shift in the relative balance of power and its economic underpinnings. Technology, by the middle of the nineteenth century, could upset the balance of power between countries.

Significance of Problem

In the twenty-first century, technology does not appear to be losing its primacy in the competition between countries. In 2014, then Secretary of Defense Chuck Hagel initiated a so-called "third offset strategy" that would enable the U.S. military to maintain its technological advantage over its adversaries in the upcoming century. The rise of adversary capabilities to counter the previous U.S. advantage using stealth and precision-guided munitions, a process called Anti-Access/Area-Denial (A2/AD) had levelled the playing field considerably. Hagel's new strategy sought to "leverage US advantages in technologies

like big data, stealth, advanced manufacturing (e.g. 3-D printing), robotics, and directed energy."[1] This "third offset" is intended to replace the current series of technological advantages currently employed as a key facet of US military strategy.

This transition will pose a significant cost to the US military budget. Basic estimates suggest a cost of at least $18 billion in the first five years alone.[2] This represents only the initial research and development, expected to turn into demonstrations that eventually can be made into the technological centerpieces of the third-offset strategy. Deputy Defense Secretary Robert Work understood that and was quoted in 2016 as saying "we don't have enough money to do what we want to do. So, what we are doing is trying to prepare as many demonstrations on advance capabilities as we possibly can for the *next* administration to determine…the way they want to go."[3] The bottom line is that the pursuit of technological advantage comes with considerable costs.

Those costs present an interesting question, which is the focus of the research presented in this paper. Assuming a technological advantage can be achieved, how long can we reasonably expect it to last? While every technological innovation throughout history has had different parameters and different results, examining historical situations in which a technological advantage has been achieved can provide some insight into how long a twenty-first century "offset" might last.

This question will be of acute importance to military strategists and the national-security community. In determining where and how

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[1] Luis Simón, "The 'Third' US Offset Strategy and Europe's 'Anti-Access' Challenge," *Journal of Strategic Studies* 39, no. 3 (April 15, 2016): 418, doi:10.1080/01402390.2016.1163260.
[2] "What Is the Third Offset Strategy? | RealClearDefense," accessed January 29, 2017, http://www.realcleardefense.com/articles/2016/02/16/what_is_the_third_offset_strategy_109034.html.
[3] "Pentagon Can't Afford To Field 3rd Offset Tech Under BCA: Frank Kendall « Breaking Defense - Defense Industry News, Analysis and Commentary," accessed January 29, 2017, http://breakingdefense.com/2016/10/pentagon-cant-afford-to-field-3rd-offset-tech-frank-kendall/.

much to invest in pursuit of new technologies, strategists and budgeteers should question the actual advantage gained. Additionally, they should explicitly determine over whom that advantage is sought. Gaining an advantage over a terrorist group or third-world government is easier and will last longer than attempting to gain one over a near-peer competitor that has similar technological-development capabilities. Fundamentally, these underlying questions should be answered before a significant investment is made in a new technology that may, or may not, provide the advantage sought.

Case Study Selection

"World War II was a watershed in the history of government policies concerned with the development of science and technology."[4] The dramatic requirements in technological development during the war provide insight into the benefits of technology to support military strategy. These requirements involved significant government direction and resources to gain advantage over the enemy. Especially in the military and national security fields, investment by government agencies increased tremendously. The United States provides a representative case. "Before World War II the U.S. government played a major role in supporting and guiding technical advance in only a few areas. One of these was agriculture. Indeed, in the years just before World War II, the federal government spent more on agricultural research than it did on research oriented toward national security."[5]

These factors suggest that the inclusion of technologies beginning with World War II are most appropriate in order to get to an understanding of the question at hand. The twentieth century provides a number of reasonable cases to analyze that involve significant

[4] Sylvia Ostry and Richard R. Nelson, *Techno-Nationalism and Techno-Globalism: Conflict and Cooperation*, Integrating National Economies (Washington, D.C.: Brookings Institution, 1995), 34.
[5] Ostry and Nelson, *Techno-Nationalism and Techno-Globalism*, 36.

government investment in a science-based technological development that sought to achieve an advantage over an adversary. The first case examined is the development of early-warning radar capability in Britain and Germany in World War II. The second case study will examine the U.S. and Soviet development of atomic/nuclear weapons during and in the immediate aftermath of World War II. The final case study is the U.S. development of stealth technology in the post-Vietnam and post-Cold War era.

Radar provides a compelling avenue to explore the advantages of technology and its application to achieve an advantage. Radar was a significant source of success in the British victory during the Battle of Britain. This would have seemed unlikely considering the Germans claimed a clear scientific and industrial advantage over the British at the turn of the twentieth century. "Even earlier, by 1870 or so, German universities had become widely regarded as the world's leaders in research and teaching in the natural sciences."[6] This combination of industrial prowess and academic integration would lead to a reasonable assumption that Germany would have the advantage over Britain in the development of radar, especially considering the initial designs were all German. That Britain, in fact, achieved the advantage makes for an especially interesting case.

Nuclear weapons also provide a stimulating case to study. The U.S. emerged from World War II with an obvious and clear advantage in the nuclear field, having spent the majority of the war preparing the revolutionary weapons that were demonstrated at Hiroshima and Nagasaki. The end of the war also represented a shift in the political landscape from a multi-polar, Euro-centric system to a bi-polar system characterized by stiff competition between the United States and Soviet Union. The U.S. originally planned to use its monopoly on nuclear

[6] Ostry and Nelson, *Techno-Nationalism and Techno-Globalism*, 46.

technology to counter the Soviets' significant advantage in troop numbers.[7] The advantage, however, especially in hindsight, was relatively short – considering the speed with which the Soviet Union was able to minimize the advantage. This case study is particularly relevant to a twenty-first century technological advantage, especially concerning advantages sought over a near-peer competitor.

Finally, stealth is also an interesting and compelling case to examine, primarily due to its longevity as an advantage. The capability was designed in the late cold war, and it was intended to be used against the Soviet Union and the Warsaw Pact. "Under both Carter and Reagan, the defense department sough to exploit the U.S. advantage in advanced technology to offset the Soviet Union's numerical superiority. This strategy made explicit one of the central assumptions of postwar U.S. defense planning: that the American lead in technology could give its armed forces a significant battlefield edge."[8] As a representative technology, stealth development provides insight into how the technology was developed and then how it was ultimately used. Expenditures to counter a near-peer competitor were then primarily employed against lesser actors, starting with Iraq in Operation DESERT STORM and then in nearly every other small conflict the U.S. has engaged since. The main question to be explored here, though, is should a new offset strategy expect to attain the same longevity of advantage enjoyed by stealth technology.

Variable Selection

Selecting the variables to examine in this study is no easy task. By examining technology and innovation, everything that influences those elements can be considered as to their role in the attainment of advantage. This study will examine four variables: political context,

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[7] Thomas G. Mahnken, *Technology and the American Way of War* (New York: Columbia University Press, 2008), 15.
[8] Mahnken, *Technology and the American Way of War*, 123–24.

scientific capacity/industrial base/resources, security, and systemic integration. While these four variables and the differences found between cases cannot and will not be all inclusive for the possibilities of attaining and maintaining an advantage, they do provide a baseline to examine the advantage itself.

Where possible, this study will fit these variables into Michael Horowitz's adoption-capacity theory of diffusion. "Adoption-capacity theory posits that the financial and organizational requirements for adopting an innovation govern both the system-level distribution of responses and the way that individual actors make decisions, as well as the subsequent implications for international politics."[9] This theory provides the context to assess advantage gained and maintained and will allow this study to approach an empirical answer to the primary question.

Political context is the first variable examined because a competitive relationship between states is what stimulates the need for advantage, technological or not. "One way of thinking about the impact of innovations is to look at the content of particular innovations and the way they influence international interactions."[10] The search for technological advantage has resulted in changes to the international political system, which in turn can strengthen or diminish the advantage itself. This means that examining the political context provides insight into why the technological advantage was sought and can shed light onto the reasons for its duration.

The scientific capacity and a nation's industrial base and available resources represent key factors. According to Horowitz's Adoption-Capacity Theory, financial intensity applied to exploiting technological capability is a major variable in determining changes to the balance of

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[9] Michael Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010), 30.
[10] Horowitz, *The Diffusion of Military Power*, 42.

power. “Financial intensity refers to the particular resource mobilization requirements involved in attempting to adopt a major military innovation.”[11] Lower costs of entry allow for a quicker and easier adoption, while higher costs may cause competitors to seek alternative methods to maintain or shift the balance of power. The baseline for capacity used in this study will be derived from the Composite Index of National Capability from the Correlates of War project.[12] “The Composite Index of National Capability (CINC) measures a state’s proportional share of six resources deemed militarily consequential: military personnel, military expenditure, steel/iron production, energy consumption, total population, and urban population. The higher a state’s share of the global totals, the higher its CINC score.”[13]

Security is the next variable explored in this study. Normally, diffusion happens when an innovation reaches a major demonstration point.[14] The ability for a nation to secure its innovations relates specifically to how long an advantage can be expected to last, however. Once a technology is used, other countries have immediate access to, at the very least, the feasibility of such a capability. This leads them directly into a decision process on whether that capability has the potential to shift the balance of power, and therefore how to respond. Countries will try to circumvent this process to get earlier notification of the potential, either through pure espionage or other technical detection capabilities. A nation’s ability to secure developing technologies and developments can affect its ability to achieve a longer advantage over its competitors.

The final variable in play in the determination of technological advantage is systemic integration. “Major military innovations are

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[11] Horowitz, *The Diffusion of Military Power*, 30–31.
[12] Horowitz, *The Diffusion of Military Power*, 6.
[13] Stephen D. Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, N.J.: Princeton University Press, 2004), 21.
[14] Horowitz, *The Diffusion of Military Power*, 8.

distinct from simpler changes because they are systems for applying military force, not just individual technologies."[15] Integration can be either physical, meaning the combination of physical capabilities, or intellectual, which refers to the integration of technology into a new use. The ability for a country to integrate a technological development into either an existing process or create new processes as part of a strategy represents a critical variable in success. "Technology is only as effective as the strategy it serves."[16] Systemic integration is a key indicator of how invested in a strategy a nation is, and gives credence to its desire to use a technological development to gain an advantage over competitors. Horowitz explores this integration through the idea of organizational capital. The ability of the organization to adapt to a technology is his complement to financial intensity.[17] Integration is the link to strategy that serves to define advantage.

Framework

The framework for this study is a straight-forward approach to examine the case studies in the context of the variables to determine advantage. Chapter 2 examines the early-warning radar development between Germany and Britain prior to August 1940. Chapter 3 explores the nuclear weapons and relations between the United States and the Soviet Union in a quest to determine the length of the advantage possessed by the U.S. in the aftermath of Hiroshima and Nagasaki. Chapter 4 studies the development of stealth technology in the context of U.S. ability to employ it against its competitors at the close of the Cold War.

Following the examination of cases, Chapter 5 conducts a comparative analysis among the variables. The intent of this analysis will be to determine if any of the variables: political context, industrial

[15] Horowitz, *The Diffusion of Military Power*, 211.
[16] Mahnken, *Technology and the American Way of War*, 222.
[17] Horowitz, *The Diffusion of Military Power*, 10.

capacity/resource availability, security, or systemic integration should take priority over any of the others. Which, if any, of the variables that emerges as important might then captivate modern-day strategists?

Finally, Chapter 6 provides a conclusion of the data with a look at implications for future technological development. With the third- offset strategy tantalizing senior Department of Defense officials, understanding the expected timeline of advantage is an especially useful tool in the modern day. Ultimately, this study will allow for a better understanding of historical technological development from the twentieth century with an eye toward informing future investment in technological capabilities.

Chapter 2

Early-Warning Radar

This chapter examines the development of radio detection and ranging (radar) systems in Europe during the period between the world wars. First, it provides a brief examination of the development of radar capability. Then, it looks at the political context, identifying Britain and Germany as the primary competitors. Then, the chapter examines the scientific capacity, industrial base, and resource requirements needed to develop the capabilities. Subsequently, it explores the primary nations' ability to secure both their technical capabilities and their intent to employ those same capabilities. Next, the chapter studies each country's ability to systemically integrate the new technology. Finally, the chapter provides an assessment as to the advantage gained by either competitor and the length of said advantage.

Radars would be used for many things, but for the sake of this analysis and brevity, this chapter will limit discussion of radar technology to just that seeking to counter a potential air threat. As the technology improved, smaller and smaller radar systems with shorter wavelengths were developed, both during WWII and after. These new radars were used for ship detection, naval and airborne fire control, and all-weather bombing capabilities. "A number of technical innovations, such as improved antenna patterns…increased accuracy."[1] Those involved in the development of radar capabilities throughout the war believed that their contribution proved decisive in the overall victory for the Allies.[2]

Radar Development

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[1] Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York, NY: Simon & Schuster, 1996), 229.
[2] Buderi, *The Invention That Changed the World*, 246.

"The principle of the reflecting qualities of radio waves upon which radar technology is founded was discovered in 1886-87 by Professor Heinrich Rudolf Hertz at the Karlsruhe Polytechnic."[3] This discovery was followed by the invention of the first practical radar in 1904 by Christian Hulsmeyer in Düsseldorf.[4] This first demonstration was executed against a barge in the Rhine river and described as a ship collision-avoidance system. Little did the inventor know that it would be a critical component to military victory in WWII. Somewhat surprisingly, radar development lay mostly dormant until the period following World War I, as resources would not be allocated during the war with governments preferring to spend scarce funds on other capabilities.[5]

Britain, in the period immediately following WWI, was fortunate to have a flourishing radio industry. "With this level of proven technology to hand and war clouds gathering over Europe, it was natural to seek a radio solution to the feared threat of attack by German bombers."[6] From this thought, beginning in 1935, Britain developed an integrated system that provided a previously non-existent early-warning capability that helped assuage the memories of the bombings of London during WWI.[7] This development resulted in the Chain Home system that proved to be a critical component in the defeat of the Germans during the Battle of Britain and successfully prevented the planned German invasion, Operation SEA LION, during late 1940.

German capability was significantly more advanced than the British during the 1930s. "The radar equipment technology of their pre-war designs may, in fairness, be judged as advanced by comparison with

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[3] David Pritchard and R V Jones, *The Radar War: Germany's Pioneering Achievement, 1904-45* (Aldershot, England: HarperCollins Publishers, 1989), 13.
[4] Pritchard and Jones, *The Radar War*, 14–24.
[5] Pritchard and Jones, *The Radar War*, 30.
[6] Colin Latham, Anne Stobbs, and Edward Fennessy, *Radar: A Wartime Miracle* (Oxford, United Kingdom: History Press Limited, 1996).
[7] Latham, Stobbs, and Fennessy, *Radar: A Wartime Miracle*, 4.

ours, in so far as they opted from the first for shorter wavelengths (down to 50 cm) and more directional aerial systems."[8] By 1938, the Germans had developed their Freya system, providing detection ranges between 40-75 km, depending on target height. Their choice of wavelengths provided considerable benefits in accuracy over the British Chain Home system, but required a greater number of stations to achieve it.[9] The Germans, however, tended to focus on short-range systems like the Freya. "Despite the opinion of pundits that Germany had no need of such systems (long-range radars), it became very clear after the beginning of the war that it would be desirable to have an early-warning radar with a range at least twice that of the Freya and, if possible, even longer."[10] Unlike the British, the Germans were not developing radar systems to counter a previously known threat; so, they focused on different capabilities, such as aircraft navigation.[11]

Political Context

The primary actors for this case study about radar development are Britain and Germany. These were the countries seeking to gain advantage over the other, especially at the outset of radar development. Further development after the beginning of WWII was significant, but it does not outweigh the initial primacy of both Britain and Germany. These countries during this time period existed in a multipolar world that functioned in an anarchic world order – meaning there was no overarching governing power. Britain functioned as an insular power, in John Mearsheimer's terminology, in that it had a large body of water between it and all potential adversaries.[12] Germany, on the other hand,

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[8] Latham, Stobbs, and Fennessy, *Radar: A Wartime Miracle*, 4–5.
[9] Pritchard and Jones, *The Radar War*, 49.
[10] Pritchard and Jones, *The Radar War*, 116.
[11] "Radar," accessed January 3, 2017, http://www.ece.umd.edu/~taylor/Electrons6.htm.
[12] John J. Mearsheimer, *The Tragedy of Great Power Politics*, Updated (New York, NY, United States: WW Norton & Co, 2014), 136.

functioned as a continental power, sharing land borders with large potential adversaries, such as France and Russia.[13] These differences help explain how each viewed the development of technology, including radar.

"With more than two states, the politics of power turn on the diplomacy by which alliances are made, maintained, and disrupted."[14] As the number of powerful states increases, each state multiplies the uncertainties about the others.[15] States are willing to ally with other states, even when their overall interests do not necessarily align, as their common interest is normally a fear of other states.[16] "With three or more powers flexibility of alliances keeps relations of friendship and enmity fluid and makes everyone's estimate of the present and future relation of forces uncertain."[17] The end of WWI saw France and England grow a steadily stronger alliance that kept Germany as its main focus. Germany allied with Italy and Japan, resulting in the Axis alliance. Germany attempted to form an alliance with Britain but was consistently rebuffed, creating additional potential for hostilities between the two states.

Germany remained a primary concern for Britain during the period following WWI. The loss of nearly three-quarters of a million men in the four-year struggle remained at the forefront of British thinking and helped drive her political decision making. The losses suffered from German air raids over the Isles was particularly poignant and influential in developing defensive techniques and technologies. The potential for a resurgent German threat, especially in the immediate aftermath of the war, however, was subordinate to the desire to ensure the type of war just fought could never be repeated. In 1934, a British report listed

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[13] Mearsheimer, *The Tragedy of Great Power Politics*, 126.
[14] Kenneth N Waltz, *Theory of International Politics* (United States: Waveland Press, 2010), 165.
[15] Waltz, *Theory of International Politics*, 165.
[16] Waltz, *Theory of International Politics*, 166.
[17] Waltz, *Theory of International Politics*, 168.

Germany as its largest potential enemy in support of a requirement to greatly expand the British Expeditionary Force. The expansion was not considered due to a lack of resources.[18]

For its part, Germany generally lacked a desire to consider Britain a threat. As mentioned before, Germany continually sought alliance with Britain during both the Weimar years and after Hitler came to power in the Third Reich. Evidenced by Britain's refusal to allow French occupation of the Ruhr in 1923 and their support for the Locarno treaties, diplomatic relations between the two countries were relatively stable.[19] Britain and Germany even agreed to a Naval Pact in 1935, limiting the size of the German Navy to 35 percent of the British Fleet in an effort to avoid the conditions that led to a naval arms race just prior to WWI.[20] The largest potential source of conflict, from the German perspective, was Britain's status as the best potential challenger to German dominance of Europe. Germany sought to limit British influence in continental Europe while maneuvering to gain the Lebensraum central to Hitler's goal of world-power status.

The differences in political objectives between Britain and Germany created a baseline security dilemma. While Britain sought to maintain the status quo, Germany did not, especially in the post-Versailles environment. "The security dilemma can not only create conflicts and tensions but also provide the dynamics for triggering war."[21] The British could not allow the Germans to rearm and develop a dominant posture in Europe without ceding some of their security, so they had to look for

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[18] Keith Neilson, Greg Kennedy, and David French, eds., *The British Way in Warfare: Power and the International System, 1856-1956: Essays in Honour of David French* (Farnham, England ; Burlington, VT: Ashgate, 2010), 120.
[19] Eberhard Jäckel, *Hitler's World View: A Blueprint for Power* (Cambridge, MA: Harvard University Press, 1981), 31.
[20] Joseph A Maiolo and King's College London, *The Royal Navy and Nazi Germany, 1933-39: A Study in Appeasement and the Origins of the Second World War* (London: Macmillan, 1998), 30–31.
[21] Robert Jervis, *Perception and Misperception in International Politics*, 13th ed. (United States: Princeton University Press, 1976), 67.

options to counter a resurgent German threat. They had to do this even knowing that a potential second world war would likely mean the end of the British Empire as it stood.

Radar as a new technology was advanced in this context. As mentioned earlier, the British feared a repeat of the bombings of London during WWI, so they had a specific and direct end-state that could focus their technological innovation. The Germans did not have a specific end-state, so their development was not precisely focused. "Any problems Germany had in the radar war stemmed not so much from its technical sophistication as from its military mindset. Hitler and his war planners thought in terms of lightning offensives, and so did not push the development of mainly defensive radars."[22]

Allocation of resources is critical in developing innovative uses for new technologies. Scientific innovation and technology development require industrial resources capable of developing and utilizing the product in support of the end-state. This resource requirement is normally limited to just the major players, for whom the development of technology can provide the panacea, or the downfall, of other military action.

Scientific Capacity/Industrial Base/Resource Constraints

The advance of technology is at least partially dependent on a nation's social policy. Richard Heilbroner tells us that "the steady expansion of scientific research…provided an increasingly important stimulus for technological advance." Radar certainly fits the mold for scientific-based technological advance, however, Heilbroner also tells us that "an advance in technology not only must be congruent with the surrounding technology but must also be compatible with the existing economic and other institutions of society."[23] Society must have a need

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[22] Buderi, *The Invention That Changed the World*, 202.
[23] Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?: The Dilemma of Technological Determinism* (Cambridge, MA: MIT Press, 1994), 62–64.

for the technology, or it will not advance. This is evidenced by the lack of interest in Hulsmeyer's 1904 radar patent. Significant improvement did not occur until after WWI and when there were additional radio technologies that coupled with a defined societal need for the advancement of radar technology.

Activities such as radar development also require a strong industrial capability capable of translating unique scientific inventions into readily useable technologies that serve their intended purpose. This industrial capacity must also be supported by the availability of significant capital resources that can be invested without damaging other critical capabilities or technologies. Both Germany and Britain, in the period leading up to WWII, had the industrial capacity and available capital to invest in developing radar technology to suit their purposes.

Germany had a strong incentive to invest in new technologies. "The Treaty of Versailles attempted to place strict limits on German rearmament but in doing so created a climate in which resources were channeled into technological innovation to compensate for or circumvent these limits."[24] Hitler's regime enabled German businesses to recover from the recession and to invest heavily in technologically advanced capabilities. "Technology, in fact, is one of the keys to understanding relations between Hitler's regime and the German business community."[25] Hitler provided the business community with a way to maintain power and benefited from the same since "the Third Reich needed German industry above all for its productive resources, both technological and organizational." Hitler set Germany on the path towards expansionist conquest in 1936 by establishing the Four-Year Plan, wherein the German army had to be operational and the economy

[24] Donald A. MacKenzie, *Inventing accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 2001), 44.
[25] Adam Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy* (New York: Penguin (Non-Classics), 2008), 114.

had to be fit for war.[26] This Four-Year Plan provided additional investment in technologically heavy industry, allowing for continued development, prioritizing military advancements. The advancements were still limited by the societal problem they sought to solve. For example, "the German development of a magnetron was limited by the lack of interest of the German military authorities."[27]

Scientifically, Britain was not as advanced as the Germans, but that did not prevent them from developing innovative technologies. Robert Watson-Watt, of the National Physical Laboratory, was working on using radio waves as a type of "death ray." In attempting to demonstrate that it would not work, researchers discovered that radio waves were affected by the presence of aircraft. Leveraging the previous German research conducted by Hertz and Hulsmeyer, the scientists knew that radio waves could reflect off solid objects. Radio detection finding was the end-result of this exploration, but it had to be converted into a useable system.[28]

Britain invested heavily in military technologies in the 1930s. "Hurricanes, Spitfires, and radar are all reminders that, in the two decades after 1918, Britain remained a major military power, often at the cutting edge of new technology."[29] With a specific objective in mind, preventing a repeat of German air attacks against the homeland, the British invested specifically in aircraft detection radar technology. "The Chain Home and Chain Home Low radars for fighter defense cost about £5M to December 1940, out of a total cost of RAF radar for research, equipment, and operation of £10M. The army radar program cost

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[26] Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy*, 222.
[27] Gaspare Galati, *100 Years of Radar* (Cham: Springer, 2016), 69.
[28] Stephen Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain* (United Kingdom: Aurum Press, 2015), 60–61.
[29] David Reynolds, *Long Shadow: The Legacies of the Great War in the Twentieth Century*, 2015, https://www.overdrive.com/search?q=EF1AB17B-DCA7-486A-9F2F-E43548CB0B21.

another £10M over the same dates, most of it concerned with air defense. The total radar equipment installed by the end of 1940 cost about the same as a battleship (£10M)."[30] As priorities were already set with a well-identified and supportable problem, significant expenditures could be easily understood.

The political objective seems to drive the ease of investment in technological systems. This focus also allowed for increased interaction between developers and users in order to innovate tactics and capabilities. "Although Chain Home was crude compared with German systems, reasonably good relations between such officers as Air Chief Marshal Sir Hugh Dowding, in charge of Fighter Command, and the scientists allowed a clear-sighted scientific program to prosper and to produce a technological lead over Germany by 1941."[31] This interaction proved to be successful and garnered improved military advantages by focusing technological innovation on a known objective.

The Composite Index of National Capability (CINC), derived from the Correlates of War Project, provides additional insight into the capacities of both countries to invest in technologies needed to fight a war. The CINC is measured in relation to the world's total capacity, so the higher share is indicative of relative power.[32] Germany and Britain had nearly equal values in 1930, with Germany having a 0.070 score to Britain's 0.078. As the 1930s progressed however, Germany started to outpace Britain, achieving a 0.171 score in 1940 compared to Britain's 0.094. Germany's investment in developing power was clearly outpacing

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30 David Edgerton, *Britain's War Machine: Weapons, Resources, and Experts in the Second World War* (Oxford: Oxford University Press, 2011), 120.
31 Peter J. Hugill, *Global Communications Since 1844: Geopolitics and Technology* (Baltimore, MD: Johns Hopkins University Press, 1999), 23.
32 Stephen D. Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, N.J.: Princeton University Press, 2004), 21.

that of Britain during the 1930s. But, the relative power does not compensate for poor strategic objectives.[33]

Security

The British implemented an extraordinarily tight security program surrounding their radar developments that ensured both their intent for its use and their new capabilities would not fall into German hands. This security included the training of individuals to maintain the radar systems as they were established throughout the country. "Personnel not directly involved in radar – especially those who risked becoming the enemy's prisoners – were denied knowledge of it."[34] The end result of their tightly implemented security speaks for itself. "As the main bombing campaign opened in mid-July 1940, a seminal survey of British air capabilities issued by Colonel Josef "Beppo" Schmid, chief of Luftwaffe intelligence, failed to mention the enemy radar net. Germany paid a heavy price for its intelligence letdown."[35]

German intelligence collection against the British system certainly happened in the late 1930s, but their ability to generate valid data was suspect. Lufthansa flew multiple sorties across Britain in the two years prior to the war, ostensibly as weather-collection flights, but actually to conduct photo reconnaissance. Those photos led to a dedicated Zeppelin flight in the summer of 1939 designed to collect electronic intelligence. Unfortunately, their receivers were focused on short wavelengths, similar to those used in German radars, and failed to pick up British aircraft detection radar that could have provided key insight into the Chain

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[33] "National Material Capabilities (v4.0) — Correlates of War," Folder, accessed January 30, 2017, http://www.correlatesofwar.org/data-sets/national-material-capabilities. *Singer, J. David. 1987. "Reconstructing the Correlates of War Dataset on Material Capabilities of States, 1816-1985" International Interactions, 14: 115-32.*
[34] Latham, Stobbs, and Fennessy, *Radar: A Wartime Miracle*, 188.
[35] Buderi, *The Invention That Changed the World*, 92.

Home system and could have altered German tactics during the Battle of Britain.[36]

The Germans seemed convinced by their own biases, however, in regard to their understanding of British radar development. As mentioned earlier, General Wolfgang Martini ordered sorties over Britain, and the Chain Home system certainly could not have been hidden from their view. The long 12-meter wavelength emitted by the Chain Home system was detected and reported, but Martini could not bring himself to believe they were using that wavelength for radar coverage, as the Germans had been using centimeter wavelengths for many years already.[37]

For their part, the Germans maintained excellent security around their own systems. "The British would doubtless have been astonished to learn that this radar [Freya] had its origins in experiments which had taken place more than ten years earlier…it is a tribute to the German Security Service that it remained a secret for so long."[38] By the time war broke out in Europe, Germany had by far the best developed and technically capable radars, largely unknown to its enemies.[39]

British understanding of German capabilities happened primarily by chance. A sympathetic German scientist provided a letter through the Naval Attaché in Oslo in 1939 detailing German developments on scientific projects. This so-called "Oslo Report" provided specific insight into German capabilities, including radar. This report was generally disregarded by British service ministries, who called it disinformation. Several British scientists, however, questioned this interpretation based on confirmation with other intelligence information. It is fascinating that, even in 1939, "Britain had no extensive organization within its

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[36] Buderi, *The Invention That Changed the World*, 91.
[37] Pritchard and Jones, *The Radar War*, 55–56.
[38] Pritchard and Jones, *The Radar War*, 53.
[39] Buderi, *The Invention That Changed the World*, 202.

Intelligence Service for securing information about German scientific progress." It took until 1941 with direct radio-communications intercepts of specific German radars in use before the British scientists were really taken seriously.[40]

The lack of knowledge by both the British and the Germans of each other's scientific development of radar is somewhat surprising. In the period leading up to WWI, there was a sense of transnational scientific cooperation, but this quieted down immediately after the war. The establishment of national research councils further limited transnational interaction, although that started to broaden in the aftermath of the Locarno treaties.[41] It seems that the concept of simultaneous invention and isolationist tendencies in the post-WWI environment explain why neither Germany nor Britain was fully aware of each other's development with respect to radar technology.[42]

Systemic Integration

Looking at radar development on its own tells only a small portion of the overall story.

The British created the Dowding system, integrating radar's ability to detect incoming German planes with fighter development and deployment as well as a robust command-and-control system to engage the incoming Luftwaffe aircraft. "All the fighters in the world were of little use if they could not find their enemy."[43] This system allowed Air Marshal Dowding the advantage of being able to manage both his pilots and their aircraft. He was able to respond only when there was an imminent threat, vice being required to keep aircraft airborne around the clock. Ultimately, it was this intellectual integration that allowed for the

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[40] Pritchard and Jones, *The Radar War*, 50–51.
[41] A. Iriye and P. Saunier, *The Palgrave Dictionary of Transnational History: From the Mid-19th Century to the Present Day*, Palgrave Macmillan Transnational History Series (United Kingdom: Palgrave Macmillan UK, 2016), 663.
[42] Smith and Marx, *Does Technology Drive History?*, 56.
[43] Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain*, 60.

stunning success of Fighter Command over the Luftwaffe during the Battle of Britain.[44]

On the German side, radar development was not focused towards a systemic integration to combat a known or perceived threat. Their capability followed from the scientific development of the early 1900s to create smaller, more efficient, and shorter-wavelength systems to be used in numerous functions. There was not a specific end goal for integration with other systems, so capabilities such as early warning, navigation, and altitude determination were given equal weight in production. While German radars routinely provided information to their fighters about incoming British aircraft, command and control for this was not centralized; so, each unit was reliant on its own resources and individual radar-detection capability. The Germans relied on a physical integration of radar technology, and paired it with existing structures and processes; which took time to develop into a coherent strategy.

Assessment of Advantage

Assessing an advantage between Britain and Germany as adversaries is not a slam dunk for this case. While it seems obvious that Britain had the advantage due to the successful use of radar during the Battle of Britain, it does not necessarily mean they had the technological advantage. By all accounts, the Germans had smaller, longer-range, more accurate, and highly mobile radars at the same time Britain developed the Chain Home system. One could argue Germany had the technological advantage in this case, but that would seemingly disregard the environment.

Using Michael Horowitz's Adoption-Capacity Theory, Germany had clearly more capacity to invest in technologies to support its quest for power as demonstrated by the CINC values described above. German financial intensity outpaced that of Britain in terms of all power-related

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[44] Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain*, 60–68.

items. Germany did not, however, demonstrate the organizational capacity for change in order to systematically integrate its technologies into the military as a whole.

What Britain did have, and the Germans did not, was a specific objective upon which to focus their innovation. The discovery and invention process was clearly in favor of the Germans, but the application process, with a clear end-state, favored the British. Their understanding of the political objective, to prevent air attacks similar in nature to those seen in WWI, allowed for a linear innovative process that combined new radar technology with the people and resources that could effectively employ it to gain the political objective. This strategy, in turn, allowed Britain to successfully defeat a more technologically capable adversary and garnered a victory in the Battle of Britain.

The German innovation process was significantly more disjointed. Radar development was not focused on a singular objective and, therefore, did not have a linear path. The radars developed were more technologically capable, but not focused on a specific end. This also clouded German ability to judge their adversary's capability, as they expected a similar level of technological development but ignored the social aspects needed to breed a successful innovation.

Can Britain be awarded a specific length of time for having a technological advantage over the Germans in the radar case? Certainly, the period of the Battle of Britain could be awarded--approximately nine months in 1940. Once Allied offensive operations started, Germany was able to transition its technology into an effective air-detection system as well, negating the "advantage" Britain held. The systemic integration employed by the British, in the form of the Dowding system, provided the overall advantage. In this case, the advantage was more strategic than technological, which Britain certainly held, at least through the Battle of Britain.

Chapter 3

Atomic Weapons

This chapter examines the development of atomic weapons during the period immediately following World War II. This study seeks to analyze the length of the advantage gained by the US over the USSR in atomic-weapon development during the early Cold War. First, this chapter briefly examines the original development of atomic-weapons capability and assesses the status of each of the primary actors at the conclusion of WWII. Then, it looks at the political context of the early Cold War between the US and USSR. Next, it explores the scientific capacity, industrial base, and resource capabilities of each country. Then, the chapter studies the ability of each to secure its technical developments from the other. Systemic integration of nuclear weapons into strategy and application is the last variable studied. Finally, this examination provides an assessment as to the advantage gained and the length of said advantage.

Significant research and development occurred in multiple countries just before and during World War II, culminating in the US employment of atomic weapons against Japan in August, 1945. These developments have been extensively researched and provide a rich assessment of the capabilities of each of the countries. An oft-asked question about Germany's decision to halt its development program warrants a mention and is succinctly answered by Adam Tooze. "With hindsight, it is clear that the decision made by Speer and his colleagues was essentially correct. Even working with virtually limitless resources, the Americans did not manage to complete a viable atomic weapon in time for it to be used against Germany."[1] Since Germany was expending a significant portion of its resources in prosecuting the war, it could not

[1] Adam Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy* (New York: Penguin (Non-Classics), 2008), 510.

afford to invest the needed financial resources to be successful. The focus here on the impact of nuclear technology in the context of development in the United States and Soviet Union is more relevant to the discussion about achieving technological advantage over competitors.

Atomic-Weapon Development

The discovery of radioactivity in 1896 played an instrumental role in understanding basic atomic structure, setting in place the necessary foundation that would allow scientists to exploit the equivalence between mass and energy. The 1930s, however, provided the concrete precursors to development of atomic weapons. In 1930, German scientists Walter Böthe and his assistant Herbert Becker discovered an experimental result inconsistent with the prevailing theory of atomic structure. In true scientific fashion, this new discovery was tested throughout the community to form a new theory. Briton James Chadwick experimented with Böthe's findings and discovered, in 1932, uncharged particles that were then named neutrons. Because neutrons are uncharged, they were very difficult to detect, but their very nature makes them extraordinarily important to the process of nuclear change.[2]

These discoveries led to a logical progression of research in atomic science. The studies were mainly focused on both naturally occurring radiation and on assisted radioactivity caused by bombarding elements with outside radiation to cause internal radioactive processes. Looking at atomic capabilities in terms of power, scientists were optimistic they could achieve energy releases, but all the experiments were done at very small levels – "not tons or grams, but fractions of micrograms."[3]

The potential for weaponry was not unnoticed during this initial discovery period. Enrico Fermi first experimented with bombarding Uranium (the most complex element known at the time) with neutrons in

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[2] Anthony Cave Brown, Charles Brown MacDonald, and United States, eds., *The Secret History of the Atomic Bomb* (New York: Dial Press, 1977), 4–8.
[3] Brown, MacDonald, and United States, *The Secret History of the Atomic Bomb*, 16.

1934 and was confused by the results achieved. Proper interpretation did not happen until Niels Bohr studied the problem in 1939. Seeking the advice of Albert Einstein to confirm his hypothesis that the bombardment of Uranium with neutrons resulted in absorption of a neutron in the nucleus, which could cause the atom to split. "This fission phenomenon had three major implications: the release of energy, the production of radioactive atomic species, and the possibility of a neutron chain reaction."[4]

While the original experiments were conducted openly and widely reported in academic journals, the potential for these systems, especially as the winds of war swirled, caused countries to move further experimentation into secrecy. As mentioned above, Germany decided not to pursue atomic weapon development. Famously, the United States invested heavily in the Manhattan Project, spending $20 Billion in constant 1996 dollars. (By contrast, the US spent $2 Billion in constant 1996 dollars to purchase 3,690 B-29s during World War II).[5] This investment paid off in 1945, with the detonation of atomic warheads over Hiroshima and Nagasaki, and finally bringing about Japan's surrender. It also ushered in a competitive era of development between the United States and the Soviet Union, which is the focus on the remainder of this chapter.

Political Context

The end of World War II brought about an opportunity for a new world order different from the previous multi-polar structure that persisted even after the close of World War I. This new order, characterized by a bi-polar competition between the United States and the Soviet Union, continued to operate in an anarchic world. The United States established global institutions, which provided some basis for

[4] Brown, MacDonald, and United States, *The Secret History of the Atomic Bomb*, 19.
[5] Michael Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010), 103.

order, but none of these institutions, including the United Nations, passed for a legitimate authority over states. The competition between the Americans and the Soviets, whether diplomatically resolved through the UN or on the battlefield in proxy wars in Korea then Vietnam, served as the defining characteristic of the post-World War II era.

Nuclear weapons and the race for nuclear superiority was, in turn, the defining material characteristic of the competition between the US and the Soviet Union. The US demonstrated nuclear-weapons capability and potential in Japan to close World War II, and their impact on future relations between great powers cannot be understated. The US was able to leverage its monopoly in the early days after World War II to counter a massive Soviet military presence in Europe. The Soviets, recognizing the impact immediately, pushed ahead with developing their own nuclear capability to counter US leverage. This competition continued throughout the Cold War.

In addition to the material competition of the nuclear arms race, the Cold War featured ideological competition between the socialist/authoritarian Soviet system and the capitalist/democratic American way of life. This competition, under the umbrella of a nuclear arms race initially and a nuclear mutually assured destruction eventually, defined interactions. The competition was not solely about getting a technological or material advantage over the other but of achieving victory for the ideology as well. Thus, the bi-polar contest of the United States and Soviet Union, the only great powers that truly mattered, was a competition through and through. This ideological divide was made crystal clear in competing speeches in 1946. Josef Stalin's speech at the Bolshoi theater in February was countered by Winston Churchill's famous "Iron Curtain" speech to Westminster College in March. The West's position was codified in George Kennan's

"Long Telegram" recognizing the irreconcilable differences and their impact on foreign policy.[6]

Just after World War II, the United States quickly realized that its nuclear monopoly could not possibly last. "The Truman administration had already decided that maintaining a long-term monopoly on nuclear weapons was untenable, making nuclear monopoly an ineffective strategic lever."[7] This did not prevent Truman from using the temporary monopoly to gain strategic advantage, though. Some senior US officials even advocated a strategy to maintain the monopoly, primarily by using preventive strikes against other nations who tried to develop the capability. This strategy was definitively rejected, however, and the diffusion of nuclear capability occurred over the following years and decades.

The Soviet understanding of nuclear capabilities on international politics was clear. "Stalin clearly perceived nuclear weapons as a difference maker in international politics – at a minimum as a psychological weapon of intimidation."[8] Shortly after the bomb fell on Hiroshima, Boris Kurchatov, the scientific director of the program to build the Soviet atomic bomb was told "build it as quickly as possible and do not count the cost."[9] Stalin believed that the US use of atomic weapons on Japan was aimed just as much at him and the Soviet Union as it was to end the war with Japan.[10]

Once both sides started the nuclear-arms race it was then impossible to stop. Soviet physicist Andrei Sakharov wrote a brilliant summary as to the nature of the arms race in his memoirs. "The Soviet

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[6] Jim Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949* (New York: Pegasus Books, 2010), 390–91.
[7] Horowitz, *The Diffusion of Military Power*, 125.
[8] Horowitz, *The Diffusion of Military Power*, 125.
[9] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 362.
[10] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 360.

government already understood the potential of the new weapon, and nothing could have dissuaded them from going forward with its development. Any US move toward abandoning or suspending work on a thermonuclear weapon would have been perceived either as a cunning, deceitful maneuver or as evidence of stupidity or weakness. In any case, the Soviet reaction would have been the same: to avoid a possible trap and to exploit the adversary's folly at the earliest opportunity."[11] Thus, as soon as both sides started pursuing nuclear weapons in competition with each other, they could not stop without the other side exploiting the perceived weakness.

In the late 1940s, nuclear monopoly gave the US two major advantages. First, it allowed the US to provide a credible counter to large masses of Soviet conventional forces. This provided the necessary resources at home through reduction of manpower actively serving under arms and returning industrial capacity to non-military production. Second, it inspired confidence in the ability of the United States to act as a major global player. Michael Horowitz sums this up with "confidence in the guarantor of US survival and threat to others provided by the atomic bomb allowed US leaders like Harry S. Truman, whether by design or not, to resist the temptation to cede Europe to the Soviet Union and retreat across the oceans back to the United States."[12] The advantage of the nuclear monopoly had a dramatic impact on international relations and cemented the superpower status of the United States, extending from the end of World War II to the present day.

The Soviets first achieved an atomic explosion in August 1949. They were fairly slow in developing nuclear capability. Data derived from the Nuclear Notebook, from the Federation of American Scientists, shows that their arsenal grew slowly with only 354 strategic warheads by 1960

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[11] Andreĭ Sakharov, *Memoirs*, 1st Vintage Books ed (New York: Vintage Books, 1992), 99.
[12] Horowitz, *The Diffusion of Military Power*, 126.

compared to 3,127 for the United States.[13] While the Soviets achieved parity in the years to follow, the early years showed a distinct disadvantage. This begs the question though, especially in the field of nuclear "diplomacy": how many nuclear warheads does a country need not to be at a disadvantage?

The 1950s brought a new nuclear policy for the United States. After Truman's decision not to use nuclear weapons against North Korea or China during the Korean War, it seemed that the weapons would be reserved only for direct conflict between great powers. Eisenhower's threats to use them to force the Korean War to a close appear to be just that, although it led to a revamping of US military doctrine to support his New Look defense plan. This new plan was designed to implement a strategy of massive retaliation. "The New Look gave high priority to SAC (Strategic Air Command) as a mainstay of massive retaliation. By contrast, the Eisenhower administration cut budgets for conventional ground forces substantially…"[14] This strategy assumed that a war with the Soviets would be a total war and therefore a nuclear war. As the Soviets developed significantly improved nuclear capability, the concept of Mutually Assured Destruction (MAD) started to take form.

The US started to shift from the strategy of massive retaliation in the 1960s under President John F. Kennedy. While the new administration benefitted from the legacy of the Eisenhower administration, it sought to bring in additional flexible options involving the use of nuclear weapons. In an early test, the Cuban Missile Crisis caused the new administration to revert back to an Eisenhower-esque

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[13] "Nuclear Notebook," *Bulletin of the Atomic Scientists*, accessed February 1, 2017, http://thebulletin.org/nuclear-notebook-multimedia.; "Nuclear Notebook | Bulletin of the Atomic Scientists," accessed February 1, 2017, http://thebulletin.org/nuclear-notebook-multimedia.

[14] Thomas G. Mahnken, *Technology and the American Way of War* (New York: Columbia University Press, 2008), 27.

policy while returning to promote flexible options after the crisis ended.[15] For their part, the Soviets seemed to remain focused on a belief that they could succeed in a nuclear conflict, and maintained a policy of rapid and massive counterforce strikes to eliminate US nuclear capability.[16] For both competitors, it was extraordinarily clear that the bi-polar nature of the competition was the only thing that mattered.

Thomas Mahnken explores one of the underlying factors guiding US policy-making during this period. Similar to the British focus in the 1930s on preventing future air attacks against London, the US had a similar cause. "Uncertainty over the size of the Soviet bomber and missile programs, combined with the legacy of Pearl Harbor, spurred fear of surprise attack."[17] The uncertainty will be discussed later under security, but the underlying worry about a surprise attack provided a clear and attainable goal for the United States to prevent a repeat of the Japanese surprise attack at Pearl Harbor. The Soviets, too, had been surprised by the German offensive in 1941 considering their previously signed non-aggression pact.

John Mearsheimer sums up the obvious conclusion. "It seems that both superpowers went to considerable lengths during the Cold War to build huge counterforce nuclear arsenals so that they could gain nuclear advantage over the other. Neither side was content merely to build and maintain an assured-destruction capability."[18] Advantage was the continuing goal.

Scientific Capacity/Industrial Base/Resource Constraints

In no other technological advance are the available industrial base and natural resources as important as in the nuclear arena. As early as

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[15] Campbell Craig, *Destroying the Village: Eisenhower and Thermonuclear War* (New York: Columbia University Press, 1998), 150.
[16] John J. Mearsheimer, *The Tragedy of Great Power Politics*, Updated (New York, NY, United States: WW Norton & Co, 2014), 230.
[17] Mahnken, *Technology and the American Way of War*, 21.
[18] Mearsheimer, *The Tragedy of Great Power Politics*, 230.

1939, famous scientist Niels Bohr made the following statement: "Yes, it would be possible to make a bomb, but it would take the entire efforts of a nation to do it."[19] This foreshadowed the incredible effort put forth by every nation that sought to develop nuclear capability to alter the balance of power in its favor.

For the Soviets, this is evidenced by their continued research into atomic development up to the invasion by Germany in 1941. In the fall of 1940, Kurchatov assessed the worldwide literature with respect to controlled fission reactions. When asked if a bomb could be built, "he said confidently that it could and estimated that a bomb program would cost about as much as the largest hydroelectric plant that had been built in the Soviet Union up to that time – an estimate low by several orders of magnitude."[20] Others were not as convinced, and the choice of investment remained with the government, not the scientists. Since a large investment would divert funds from the Soviet Union's ability to prosecute the war conventionally, the choice was to limit investment.[21]

Examining the financial-intensity element of the Adoption-Capacity Theory, Michael Horowitz understands that "by all measures, acquiring nuclear weapons is an intensive financial process."[22] Countries do not just have to invest in the nuclear capability itself, but also in a means to deliver it. Additionally, the resource constraints, namely that countries need access to uranium or plutonium in significant quantities, set the threshold for adoption quite high. Horowitz also realizes that the barriers to entry now are significantly lower than they were in the 1940s and 1950s. The science behind nuclear capabilities is well known, and new players will not invest in the wrong research paths, as did the US

[19] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 15.
[20] Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1996), 40.
[21] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 42.
[22] Horowitz, *The Diffusion of Military Power*, 103.

during the Manhattan Project. This seems to provide somewhat of an advantage, but the costs are still extraordinarily high to gain a nuclear capability.

As a prime example of the capacity required, the Combined Industrial National Capacity (CINC) data provided by the Correlates of War project present a compelling story. At the close of World War II, the United States had a CINC value of 0.38.[23] This means that the United States controlled 38 percent of the world's industrial capacity in terms of capability to wage war. This considerable advantage over every other country in the world afforded the US the unopposed opportunity to take the risks needed to develop into a nuclear superpower.

Esteemed political scientist Robert Gilpin describes the aftermath of World War II. "At the close of World War II the economic and military supremacy of the United States over other countries was of such magnitude that economists and officials regarded the problem to be exactly opposite: how to insure a sufficient flow of financial resources from the United States to other countries to keep the international economy in balance. Within a few decades, the revival of European and Japanese economies and the unanticipated growth of Soviet military capabilities dramatically reversed this situation that had been so favorable for the United States."[24] His comparison between the change of hegemonic power from Britain to the United States assumed a need to find a way to finance their new-found power, but World War II took care of that issue.

Gilpin's assessment of the shift in power is corroborated by the CINC data, especially with respect to the Soviet Union. Soviet CINC

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[23] "National Material Capabilities (v4.0) — Correlates of War," Folder, accessed January 30, 2017, http://www.correlatesofwar.org/data-sets/national-material-capabilities. *Singer, J. David. 1987. "Reconstructing the Correlates of War Dataset on Material Capabilities of States, 1816-1985" International Interactions, 14: 115-32.*

[24] Robert Gilpin, *War and Change in World Politics* (Cambridge: Cambridge University Press, 1983), 173.

values dramatically increased from 0.122 in 1946 to 0.181 in 1950. The United States' corresponding values decreased to 0.284 in the same period. The rise of the rest of the global community continued this trend, where the United States and Soviet Union achieved near parity in CINC values in the late 1960s, with the Soviet Union actually gaining a slight advantage by the early 1970s.[25]

The US did not think the Soviet industrial capacity in the late 1940s was capable of producing an atomic weapon. General Leslie Groves, commander of the Manhattan Project, believed that the US would maintain a monopoly for at least twenty years.[26] As late as 1948, he "wrote dismissively in the *Saturday Evening Post* that the Soviet Union simply does not have enough precision industry, technical skill or scientific numerical strength to come even close to duplicating the magnificent achievement of the American industrialists, skilled labor, engineers and scientists who made the Manhattan Project a success."[27] Groves, however, did not understand Stalin's willingness to invest heavily in achieving nuclear parity with the United States.

The United States and the Soviet Union both expended tremendous amounts of resources into the nuclear arms race throughout the Cold War. The strategy initially seemed to depend on the false axiom that more is always better. Once the Soviets started to increase their production capacity, they continued to produce more and more weapons, "ending up with 11,320 strategic nuclear weapons in 1989, the year the Berlin Wall came down."[28] The search for advantage in nuclear capability, however, was not to be found in numbers. After the 1950s, neither country achieved a reasonable advantage, and mutually assured

[25] "National Material Capabilities (v4.0) — Correlates of War."
[26] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 210.
[27] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 211.
[28] Mearsheimer, *The Tragedy of Great Power Politics*, 229.

destruction actually founded a fairly stable international structure after the Cuban Missile Crisis.

Security

From the very beginning, security played an extremely important role in the development and protection of advantage in exploitation of nuclear technology. As mentioned above, initial findings were widely reported in the scientific community and further advancement was not centrally located in one, or even just a few, countries. Once a country decided to pursue development of weapons, however, the continuing research was cloaked in classification levels to prevent others from accessing new discoveries. "The successful development and use of an atomic weapon required that the activities of the Manhattan District be afforded the highest possible degrees of security."[29]

The decision to classify nuclear-weapon development led directly to increased efforts at the national level to determine the capabilities. These efforts ranged from primarily espionage efforts in the 1940s to the creation of tactical and strategic-level reconnaissance capabilities in later years to determine specific capabilities. All of these efforts had varying levels of impact on the development of the weapons, first, and subsequently on the attaining or maintaining of advantage in the nuclear realm.

In *Dark Sun*, Richard Rhodes provides an excellent summary of Soviet efforts to infiltrate the Manhattan Project and to provide the Soviet Union the capability to match US production. The Soviet effort was largely successful in the long-term. By January 1945, the Soviet Union had at least two spies in place at Los Alamos.[30] These spies were able to provide the necessary details and specifications that allowed the Soviets significant progress in their own development. "The world learned about

[29] Brown, MacDonald, and United States, *The Secret History of the Atomic Bomb*, 200.
[30] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 145.

plutonium at Nagasaki (Aug 1945)…thanks to Klaus Fuchs (Soviet spy at Los Alamos), the Soviet scientists learned about plutonium early in 1943."[31]

The Soviet espionage effort had a significant impact on the ability of the United States to maintain an advantage from the 1950s on. Judge Irving Kaufman provided the following summary as he sentenced two of most infamous spies, Julius and Ethel Rosenberg, to death. "I believe your conduct in putting into the hands of the Russians the A-bomb, years before our best scientists predicted Russia would perfect the bomb, has already caused, in my opinion, the Communist aggression in Korea, with the resultant casualties exceeding fifty thousand and who knows but what millions more innocent people may pay the price of your treason. Indeed, by your betrayal, you undoubtedly have altered the course of history to the disadvantage of our country."[32]

Espionage played a clear role in the loss of advantage. For their part, the Soviets did not feel at all guilty about emplacing spies in the midst of their allies, since the US and UK consciously decided to exclude the Soviets, who were their primary allies during World War II, from the atomic-development program. This loss of advantage was confirmed with the development of hydrogen bombs, with the Soviets narrowing the imitation time to approximately nine months. The US detonated its first hydrogen bomb in November 1952 and the Soviets were able to replicate the demonstration in August 1953.[33]

Individual espionage actions were not the only security threats faced during this period. "The birth of the U.S.-Soviet nuclear competition, the secretive nature of the Soviet regime, the geographic depth of the Soviet Union, and the U.S. technological base all spurred

[31] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 77.
[32] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 480.
[33] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 469–72.

the United States to pursue air and space reconnaissance technology."[34] The US struggled to understand the extent of the Soviet capabilities so it could better exploit its own advantage in the early days or endure relative parity in later years. It was US airborne reconnaissance in early September 1949 with the WB-29 collection platform, in conjunction with civilian laboratories in the US, that confirmed Soviet nuclear capability.[35] This also led to an explosion in technological development centered around gathering as much intelligence as possible against the competing nuclear threat.

The US had great difficulty in assessing the Soviet nuclear capability and its potential delivery methods. The 1954 revelation of the Soviet M-4 bomber and later that year the jet-powered Tu-16 Badger caught US intelligence analysts by surprise.[36] The National Intelligence Estimate that year "admitted that the United States had no firm current intelligence on what guided missiles the Soviets were developing."[37] This led to a perception about a potential bomber and missile gap with assessments from senior US officials that the US may have lost its technological superiority over the Soviets.[38] It also led to dramatic overestimation of Soviet capability, which in turn helped alter national policy. For example, when Truman was deciding whether to proceed with the development of the Hydrogen bomb, he first wanted to know if the Soviets were capable of building the same weapon. Once informed in the affirmative, he responded "in that case, we have no choice."[39]

Fortunately, American ingenuity led to the development of first the U-2 airborne reconnaissance platform and ultimately the space-based

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[34] Mahnken, *Technology and the American Way of War*, 17.
[35] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 371.
[36] Mahnken, *Technology and the American Way of War*, 19.
[37] Mahnken, *Technology and the American Way of War*, 21.
[38] Mahnken, *Technology and the American Way of War*, 22.
[39] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 457.

reconnaissance programs. The U-2 helped deflate the overestimates of the Soviet bomber force, but their counter-technology like advanced surface to air missiles led to further development in the reconnaissance field.[40] These technological advances still play a major role in US technological capability and provide crucial intelligence on not just nuclear capabilities but all kinds of strategic, operational, and tactical-level developments.

The ability of the US to keep its nuclear capability secret and thus advantageous was known to be an impossibility. In September 1945, just one month after the bombings in Japan, the civilian scientists at Los Alamos issued a statement that confirmed this fact. "The development of the atomic bomb has involved no new fundamental principles or concepts; it consisted entirely in the application and extension of information which was known throughout the world before intensive work started. It is therefore highly probable that with sufficient effort other countries, who may in fact be well underway at this moment, could develop an atomic bomb within a few years."[41] While the Soviets had significant help from their ability to infiltrate the Manhattan Project, they likely would have been able to create their own capability but on a somewhat elongated schedule.

Security played a critical role in the nuclear revolution. Secrecy was often difficult, especially for the scientists responsible for creating the weapons. In a speech to his fellow Los Alamos scientists in November 1945, Robert Oppenheimer said: "that the almost unanimous resistance of scientists to the imposition of control and secrecy is a justified position, but I think the reason for it may lie a little deeper. I think that it comes from the fact that secrecy strikes at the very root of what science is, and what it is for. It is not possible to be a scientist

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[40] Mahnken, *Technology and the American Way of War*, 19–23.
[41] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 209.

unless you believe that it is good to learn."[42] Even with the resistance from those directly responsible for creating it, security was a necessary requirement for a competitive advantage.

Systemic Integration

The integration of nuclear weapons into national strategy is important to using them to gain an advantage. Michael Horowitz implies their importance to organizations since "the use of nuclear weapons shifts the organization of military power because it changes the range of possible ways a state can destroy a target."[43] It is difficult to discuss systemic integration, however, because nuclear weapons are able to exist outside of normal structures. They are not necessarily the realm of any particular military service, or even of a military at all. "While the different services can and do jockey for control of nuclear weapons, it is also possible to operate a nuclear arsenal outside the normal command structure, as the Soviet Union showed."[44]

At the beginning, the United States employed nuclear weapons as just another weapon as part of its strategic-bombing strategy. This strategy evolved under President Dwight D. Eisenhower in the 1950s. Eisenhower developed policies and constraints that, in large part, kept the United States and the Soviet Union from fighting a nuclear war. Eisenhower believed that any conflict between the US and Soviets would quickly become a nuclear conflict and that such a conflict could not include a "limited" exchange of weapons. Basically, any war with the Soviets would be a general war.[45] Additionally, Eisenhower reduced his conventional-force capabilities to ensure the only potential response would be a massive nuclear retaliation. By persuading potential enemies

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[42] J. Robert Oppenheimer, Alice Kimball Smith, and Charles Weiner, *Robert Oppenheimer, Letters and Recollections* (Cambridge, MA: Harvard University Press, 1980), 317.
[43] Horowitz, *The Diffusion of Military Power*, 101.
[44] Horowitz, *The Diffusion of Military Power*, 101.
[45] Craig, *Destroying the Village*, 49.

that limited options did not exist and that he was willing to unleash all-out war, Eisenhower was able to convince everyone that the only potential option, save a diplomatic resolution, was the destruction of both societies.[46] The strategy remained in place through the Cuban Missile Crisis in 1961, even though the Kennedy administration was trying to enforce a flexible-options strategy.[47]

While relatively little is known about the Soviet doctrine, many political scientists have tried to assess their policies. John Mearsheimer provides a compelling argument that explains where the Soviets stood during the majority of the Cold War. "It is apparent that Soviet planners never accepted U.S. thinking about limited nuclear options. Instead they seemed to favor a targeting policy much like the U.S. policy of massive retaliation from the 1950s. Specifically, they maintained that the best way to wage a nuclear war and limit damage to the Soviet Union was to launch a rapid and massive counterforce strike against the entire war-making capacity of the United States and its allies."[48]

Returning briefly to Horowitz's Adoption-Capacity Theory, his organizational-capital variable seems to counter the financial intensity factor described above. Countries do not necessarily need to invest heavily into organizational changes to be a successful nuclear power. Since the power of nuclear weapons extends far past the experience of any military service, there does not necessarily need to be a major adjustment.[49] States can choose to make major organizational investments, as the United States did with Strategic Air Command, but it is not required. Therefore, systemic integration from an organizational perspective is much less important than it is from a strategy perspective. It seems that the early strategy for both the United States and the Soviet

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[46] Craig, *Destroying the Village*, 69.
[47] Craig, *Destroying the Village*, 110–11.
[48] Mearsheimer, *The Tragedy of Great Power Politics*, 230.
[49] Horowitz, *The Diffusion of Military Power*, 105.

Union, that of massive retaliation, in fact provided the necessary incentive to avoid conflict altogether.

Assessment of Advantage

"The American monopoly would last less than five years."[50] This is not necessarily a shock to most historians. The US invested heavily in the 1940s to gain its initial advantage, achieving an extraordinary advantage that played a major role in shaping the political landscape in the post-World War II era. The initial monopoly allowed the United States to counter Soviet conventional-force superiority and even provided the confidence necessary to resist Soviet exploitation during crucial events like the isolation of Berlin in 1948.

The Soviets quickly recognized the importance of the development of nuclear technology. "Even before the formal Japanese surrender, Stalin had decided that the Soviet Union must have atomic weapons in its arsenal."[51] The Soviets moved fast, exploiting every possible opportunity, including embedding spies into the Manhattan Project, in order to mitigate the technological advantage gained by the United States.

Once the Soviets demonstrated their initial capability in 1949, the US became resistant to use nuclear weapons again, even while it retained numerical superiority. Truman approved the creation of the Hydrogen bomb to be used primarily as a bargaining chip.[52] His objective to use nuclear weapons as an instrument for peace set the standard for US policy in the future. "Truman thus began what became a US presidential tradition of maintaining and enlarging a threatening

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[50] Mahnken, *Technology and the American Way of War*, 17.
[51] Baggott, *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*, 360.
[52] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 407.

nuclear arsenal he had no intention of using except for political leverage in international negotiations."[53]

Any attempt to identify an advantage after the end of the monopoly will be fraught with assumptions and will also be wishful thinking. Once the capability to respond in kind was developed, both countries realized that each could be utterly destroyed. The only question that remained was whether or not war would be worth it. While the world came to the brink a few times, cooler heads ultimately prevailed, and wartime use of nuclear weapons remained limited to just the two dropped by the United States against Japan in August 1945, ending World War II. The sheer destructive power of this technological development precludes that awarding of an advantage beyond the point where only a single country possessed the capability. Therefore, the end of the monopoly in 1949 was also the end of the advantage.

[53] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*, 408.

Chapter 4

Stealth

This chapter examines the development of stealth technology in the period following the Vietnam War. This study seeks to analyze the length of the advantage gained by the United States over other nations, especially after the culmination of the Cold War. Reducing this analysis to just a single adversary would be pointless, as the US has used stealth technology against multiple adversaries over a period of decades. First, this chapter examines the original development of stealth technology as a response to rapidly developing air-defense systems. Then, it looks at the political context of the post-Cold War era where the US realized its position as a single superpower. Next, the chapter explores the industrial base and resource capabilities of the US and of its adversaries during the post-Cold War period. Then, it examines the ability of the US to secure its development of stealth, enabling a longer-duration advantage than previously seen in other cases of technological development. In the penultimate section, this chapter studies the systemic integration of stealth and precision-guided munitions. Finally, this case provides an assessment as to the advantage gained by developing stealth technology and additionally discusses the surprising duration of the US's advantage.

Stealth Technology Development

Stealth is a unique case to study, as it seems to be purely American exploration. "Stealth was, indeed, invented rather than discovered."[1] Most military aircraft designers in the early 1970s did not believe that radar cross section (RCS) could be reduced significantly enough to matter. Because of the fourth root properties of radar reflection, reducing the RCS by half would only provide a one-sixth

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[1] Bill Sweetman, *Lockheed Stealth* (St. Paul, MN: MBI Pub. Co., 2001), 9.

reduction in detection range. "Designers naturally concluded that RCS was an unrewarding area and spent little engineering effort on it."[2]

"The first stealth systems were a natural response to the advent of radar, which had advanced from a technical gimmick to a crucial weapon by mid-1940."[3] Like many technological advances of the mid-twentieth century, German scientists were at the forefront of technical thought. Two German aircraft designers first proposed using radar-absorbent material on airplanes, designing a prototype during World War II. They included carbon amidst sawdust and adhesive sandwiched between plywood to form a skin material. Some of this was due to material shortages in Germany during the war, but the use of carbon was specifically to absorb radar waves, reducing the aircraft's detectability to radar.[4]

Over the next few decades, aircraft designers and manufacturers continued to study radar-absorbent materials for use in reducing detectability of aircraft to radars. Development of the U-2 and SR-71 reconnaissance airplanes took a central role in the play for countering adversary air-defense radar systems. These aircraft were the embodiment of two of the three variables that could be used to exploit adversary air defenses: altitude, speed, and RCS.[5] The founder of Lockheed's famous Skunk Works section, Clarence "Kelly" Johnson, argued in 1958 specifically to focus on the altitude and speed variables. The altitude variable had already been proven by the U-2, and the SR-71's predecessor, the A-1, was already under development in the Skunk Works design shop.[6] President Eisenhower, however, had a different

[2] Sweetman, *Lockheed Stealth*, 9.
[3] Sweetman, *Lockheed Stealth*, 10.
[4] Sweetman, *Lockheed Stealth*, 11.
[5] Curtis Peebles, *Dark Eagles: A History of Top Secret U.S. Aircraft Programs* (Novato, CA: Presidio, 1995), 135.
[6] Ben R. Rich and Leo Janos, *Skunk Works: A Personal Memoir of My Years at Lockheed*, 1st ed (Boston: Little, Brown, 1994), 197.

idea. "But the president was less interested in performance and more intent on pushing for the lowest radar cross section possible. It wasn't that he just didn't want to get us shot down – he didn't want the Russians to know we were even up there."[7]

"By the early 1970s, a reduced radar cross section became the dominant consideration in the design of new aircraft. This became known as 'stealth'."[8] Ultimately, "stealth is just camouflage."[9] Because of the fourth-root rule, designers knew that they would have to achieve RCS reductions by factors of hundreds and thousands, not just the ten percent results that were so successful in the field. Even US Air Force researchers did not believe that designers could achieve these numbers.[10] In 1974, though, Skunk Works engineers started to develop a concept called faceting, in which angled-flat surfaces replaced the traditional curved surfaces prominent in aircraft design.[11] Coupled with computer coding used to calculate RCS for the angular design, Skunk Works realized that it had found a potential solution. "Although it had become clear to Lockheed that a multifaceted aircraft would present a highly-reduced radar cross section to enemy radar networks, it was not immediately clear how to make an unstable aircraft perform well in the air."[12]

This led to the awarding of the XST contract to Lockheed by both the US Air Force and the Defense Advanced Research Projects Agency (DARPA). It also led to the first classification of stealth technology, under the HAVE BLUE program name.[13] Once the DoD and the US Air Force

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[7] Rich and Janos, *Skunk Works*, 197.
[8] Peebles, *Dark Eagles*, 135.
[9] Sweetman, *Lockheed Stealth*, 35.
[10] Sweetman, *Lockheed Stealth*, 23.
[11] Steve Pace, *Lockheed Skunk Works* (Osceola, WI: Motorbooks International, 1992), 220.
[12] Pace, *Lockheed Skunk Works*, 221.
[13] Sweetman, *Lockheed Stealth*, 29.

finally began to understand the value of this new stealth technology, and the actual potential to achieve RCS reductions on levels that were orders of magnitude, a new era was sprung that led to dependence on stealth aircraft to meet national-security objectives. The rest is history. The F-117A was followed by Northrop's B-2 bomber, and all future designs were developed with stealth in mind.[14] Development in the 1990s and early into the twenty-first century added additional capabilities, including super-cruise and integrated avionics for the F-22, but the reduced RCS remained the paramount design feature.[15] This continues in the twenty-first century, with the F-35 and B-21 in the early operational phase and early developmental stage of development, respectively.

Political Context

As mentioned above, reducing this analysis to just one set of adversaries would be futile, considering the US has, in fact, used stealth technology against multiple adversaries over a period of decades. Designed for initial use against the threat of the Soviet Union, it has been employed against adversaries such as Iraq, Afghanistan, Libya, Panama, and even against non-state actors such as Al-Qaeda and ISIS. This makes the analysis of the advantage of stealth more complex than the previously examined cases.

Stealth was born in the midst of the Cold War. Vietnam served as the proving ground for ground-based air defenses to provide a major impact against attacking air forces. The success of North Vietnamese air defenses, largely supplied by the Soviet Union, led the Soviets to invest heavily in air defense as a strategy to contest the US's ability to strike with long-range aircraft. "In the early 1970s, Russia developed and deployed advanced early-warning radar networks, improved radar-guided surface-to-air missiles, and better fighter-interceptor planes with

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[14] Rich and Janos, *Skunk Works*, 312.
[15] Sweetman, *Lockheed Stealth*, 87.

lookdown-shoot-down radar systems."[16] These new systems "presented a significant threat to conventional US aircraft."[17]

The seriousness of the Soviet threat was highlighted by the Yom Kippur War in October 1973. The SA-6 surface-to-air missile employed by the Egyptian and Syrian armies confounded the Israelis who did not have the proper countermeasure equipment for this new threat to their ability to gain air superiority. The Israelis were able to overcome early failures, but they learned a valuable lesson, from which the US was able to gain beneficial insight. "As long as U.S. countermeasures and tactics were specifically tailored to enemy radars and SAMs, they would be vulnerable to technological surprise."[18] This led to significantly higher US investment in capabilities that led to RCS reductions in order to minimize that risk of surprise.

For the Soviet Union, the US shift to a disparate technology to counter their air-defense capabilities had a profound impact on its ability to maintain a balanced competition with the United States. Throughout most of the Cold War, the Soviet Union had sought to expand its influence as far as possible. During the early period, this expansion was in Eastern Europe, Northeast Asia, and the Persian Gulf. After the West was able to establish a solid containment policy, the Soviet efforts were generally limited to the third world. This desire to expand changed in the late 1980s.[19]

John Mearsheimer summarizes the first wave of scholarly explanation for the shift in Soviet policy as a sudden reversal after decades of competition as "a fundamental transformation in their thinking about international politics in the 1980s."[20] In a sense, this

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[16] Pace, *Lockheed Skunk Works*, 219.
[17] Pace, *Lockheed Skunk Works*, 219.
[18] Peebles, *Dark Eagles*, 140.
[19] John J. Mearsheimer, *The Tragedy of Great Power Politics*, Updated (New York, NY, United States: WW Norton & Co, 2014), 198–201.
[20] Mearsheimer, *The Tragedy of Great Power Politics*, 202.

first wave of analysis explained the transformation as a victory for the liberal viewpoint of international relations. The Soviet Union had realized that liberal institutions would afford better economic prosperity through the cooperation of states. Further analysis would show, however, that these initial assessments were likely backwards.

"The Soviet Union and its empire disappeared in large part because its smokestack economy could no longer keep up with the technological prowess of the world's major economic powers. Unless something drastic was done to reverse this economic decline, the Soviet Union's years as a superpower were numbered. To fix the problem, Soviet leaders sought to gain access to Western technology by greatly reducing East-West security competition in Europe, liberalizing their political system at home, and cutting their losses in the Third World. That approach backfired because political liberalization unleashed the long-dormant forces of nationalism, causing the Soviet Union itself to fall apart."[21] In this sense, Western investment in technologies like stealth are directly linked to the economic collapse of the Soviet Union and the end of the Cold War.

The end of the Cold War introduced new challenges for the United States as it navigated the new global structure. "Following the dissolution of the Soviet threat, the long American preoccupation with nuclear deterrence became displaced by a new need to prepare for a resurgence of regional conflict around the world."[22] Local conflicts that had generally been kept in check by the overarching competition between the US and Soviet Union now had the opportunity to flare up.

The US struggled with the dichotomy of a reduced existential threat but an increased operational tempo due to increases in low-intensity conflicts around the world. The US, attempting to realize a peace dividend after the Cold War ended, enacted a drawdown that

[21] Mearsheimer, *The Tragedy of Great Power Politics*, 202.
[22] Benjamin S. Lambeth, *The Transformation of American Air Power*, Cornell Studies in Security Affairs (Ithaca, NY: Cornell University Press, 2000), 153.

significantly reduced the size of all the military services and cut the number of overseas air bases by nearly 50 percent. However, "from 1991 to 1994, the Air Force participated in 194 global military operations other than war, almost twice the number of such operations it was tasked to perform during the preceding five years that coincided with the end of the Cold War."[23] This increase in operations, even during a drawdown of forces, is indicative of the "new world order" envisioned by President George H.W. Bush. This order sought to establish the United States as the arbiter and enforcer of global norms and set the benchmark for US involvement in the post-Cold War era.[24] This involvement happened in places like Panama, Bosnia-Herzegovina, Kosovo, Somalia, Iraq, and Afghanistan.

US foreign policy has changed little since the end of the Cold War. The attacks of September 11, 2001, caused a tighter focus on the problems of terrorism, but many other aspects of foreign policy have not changed. One significant change is the return to a policy of preventative action, vice solely preemptive. The invasion of Iraq in 2003 was enabled by this new policy, where war was needed to prevent both the use or spread of weapons of mass destruction and to break the link between Saddam Hussein and Al-Qaeda. While both assertions were eventually proven false, the policy endured.[25]

As the twenty-first century progresses, the status quo in place since the end of the Cold War cannot be expected to continue. Growing political, economic, and military powers like China and Russia threaten to challenge the US's position as a single superpower who can arbitrate and enforce global norms. Both countries have watched the United

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[23] Lambeth, *The Transformation of American Air Power*, 154.
[24] "George Bush: Address Before a Joint Session of the Congress on the State of the Union," accessed March 8, 2017, http://www.presidency.ucsb.edu/ws/?pid=19253.
[25] Steve Jones, "How Did US Foreign Policy Change after 9/11?," *ThoughtCo*, accessed March 8, 2017, https://www.thoughtco.com/us-foreign-policy-after-9-11-3310293.

States act in relatively low-intensity conflicts for decades. The technologies and tactics used may be less effective in the future because of active demonstrations during this time. China's rise is somewhat problematic because it throws US-centric policies and alliances into potential disarray. As China's capabilities increase, its potential threat to US interests also increases. This will force the US to pay more attention to China, as evidenced by the 2011 "pivot to the Pacific" policy of the Obama administration.[26] While this "threatening" posture is purely a realist approach to understanding the situation, it is eminently appropriate considering the actions of both countries in responding to China's advancing capabilities.[27]

The future of technologies, including stealth, will help sort out the eventual balance of power in the twenty-first century. "Throughout the ages, it has been an iron law of weapons development for new concepts to be negated eventually by offsetting countermeasures. Naturally, in the case of low observability to radar, one can assume that adequately endowed adversaries will seek aggressively to unmask such aircraft either through more-capable radars or through sensors based on other physical principles, such as infrared, visible light, and acoustics."[28] China is actively developing countermeasures to nearly all visible US technologies, including stealth. As the US is again forced to face a capable competitor, it will be forced to reevaluate its current technologies to ensure they are still capable in case of conflict.

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[26] Mark E. Manyin et al., *Pivot to the Pacific? The Obama Administration's "Rebalancing" Toward Asia*, CRS Report for Congress (Washington, D.C: Congressional Research Service, March 28, 2012), https://fas.org/sgp/crs/natsec/R42448.pdf.
[27] Feng Zhu, *China's Ascent: Power, Security, and the Future of International Politics*, ed. Robert S. Ross, Zhu Feng, and Susan Leigh Star (United States: Cornell University Press, 2008), 295.
[28] Lambeth, *The Transformation of American Air Power*, 157.

Scientific Capacity/Industrial Base/Resource Constraints

Stealth followed a long line of advanced research projects that enabled the United States to gain and then maintain a technological edge over its potential adversaries. Like all other advances of cutting-edge technologies, stealth requires a significant industrial capability with the underlying capital and scientific investments that allow for direct innovation. Lockheed's Skunk Works division is a prime example of how the US is able to invest in advanced technologies.

Formally called Advanced Development Projects, Skunk Works was at the cutting edge of technology for nearly every new aeronautical advance since the 1940s. The division represented Lockheed's understanding that new technologies would be useful and that the ability to develop them quickly and secretly would enable the US to maintain an advantage over its adversaries. Some of the Skunk Works' main successes over the decades span the range from the F-80 Shooting Star during World War II, the U-2 and SR-71 reconnaissance planes during the early Cold War, to the F-117A at the end of the Cold War, and now on to the F-22 and F-35 for the twenty-first century challenges.[29] Similar divisions at other major defense companies, such as Boeing's Phantom Works, provide the scientific, industrial, and financial capital needed to produce advanced technologies able to meet the national security challenges faced by the United States.

The initial investment into stealth design was both a lesson learned from the Vietnam War and a search for a way to conventionally compete with Soviet air-defense technology. "The development of stealth was a part of a strategy for competing with the Soviet Union. One of the main arguments for going ahead with the B-1 Lancer and later the B-2 was to impose on Moscow the tremendous cost of modernizing the Soviet

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[29] Pace, *Lockheed Skunk Works.*

Union's territorial air defense."[30] Knowing that resources were limited, especially at the edge of technological advance, imposing ever-increasing cost requirements on the Soviets through new capabilities helped ensure that the US could gain a significant advantage in the conventional realm. For Secretary of Defense Casper Weinberger, by 1987 "the ability of the United States to penetrate Soviet air space had already forced the Soviets to invest the equivalent of over $120 billion in strategic air defense."[31]

For the Soviets, it was not that they did not have the scientific wherewithal or industrial capacity to create stealth technology. In fact, an article published by Soviet physicist Pyotr Umfistev about edge waves and diffraction was translated by US intelligence in 1971 and played a central role in Lockheed's bid for the HAVE BLUE contract.[32] The Soviets simply chose to invest in air-defense technologies as a counter to US force-projection capabilities.

The Combined Industrial National Capacity (CINC) data provided by the Correlates of War project show that the United States and Soviet Union had a near parity in overall industrial capacity in the last decade of the Cold War. The Soviets actually had a slightly higher value than the US throughout the period until the Soviet Union collapsed. Values for the Soviet Union were 0.16 to 0.17 between 1980 and 1989. The United States maintained values from 0.12 to 0.13 over the same period.[33] Essentially, both countries had the same overall capacity, as the relative difference was not enough to provide a significant advantage.

In the post-Cold War era, it is difficult to determine which countries might have the incentive to build and employ stealth aircraft.

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[30] Thomas G. Mahnken, *Technology and the American Way of War* (New York: Columbia University Press, 2008), 163.
[31] Mahnken, *Technology and the American Way of War*, 164.
[32] Pyotr Ufimtsev, *Method of Edge Waves in the Physical Theory of Diffraction*, Technical Report (Wright Patterson AFB, OH: National Air Intelligence Center, 1971).
[33] "National Material Capabilities (v4.0) — Correlates of War," Folder, accessed January 30, 2017, http://www.correlatesofwar.org/data-sets/national-material-capabilities.

None of the countries the US has employed stealth technology against have the capacity to build their own airplanes, much less advanced technological designs. Just as an example of the polarity of the competition, Iraq in 1990 had a CINC value of 0.012 compared to the US's 0.14.[34] That order of magnitude difference is striking, and indicative of the US's wide advantage over non-peer competitors. Remember, Iraq in 1990 had the fourth largest army in the world.[35]

In more recent times, both China and Russia have invested somewhat in developing their own stealth capabilities. For the Chinese, this is included as part of their military-modernization program that seeks to gain parity with US capabilities. For its part, stealth development started in the early 2000s with work on their J-X fighter.[36] China revealed its seventh upgraded version, the J-20, in 2016.[37] But, like the Soviets, the Chinese have focused mostly on defensive counter capabilities, building an anti-access/area denial strategy and implementing the capabilities to enable success. The Chinese model is founded on a term called *shashoujian*, which "refers to a set of military capabilities that enables the technologically inferior to defeat the technologically superior."[38] While China is developing stealth capabilities, it is more focused on countering US offensive capabilities to deny the US access to its interests.

The Russians are also attempting to build a stealth fighter but remain primarily focused on their air-defense posture as a means to

[34] "National Material Capabilities (v4.0) — Correlates of War."
[35] James Kitfield, *Prodigal Soldiers*, Brassey's paperback ed, An AUSA Institute of Land Warfare Book (Washington, DC: Brassey's, 1997), 336.
[36] "Chinese Stealth Fighter Plans Revealed," *New Scientist*, accessed March 8, 2017, https://www.newscientist.com/article/dn3174-chinese-stealth-fighter-plans-revealed/.
[37] "Stealthier Stealth? Seventh Upgraded Chinese Stealth Fighter Prototype Aims to Take Flight," *Popular Science*, accessed March 8, 2017, http://www.popsci.com/stealthier-stealth-seventh-upgraded-chinese-stealth-fighter-prototype-aims-to-take-flight.
[38] Jeff Reilly, "Multidomain Operations: A Subtle but Significant Transition in Military Thought," *Air and Space Power Journal* 30, no. 1 (Spring 2016): 66.

counter the US stealth advantage. The Sukhoi T-50 work began in 2002 and is still yet to become operational. The Russians are learning that the financial investment in stealth technology is significant and often struggle with all of the requirements for a successful airframe. "Stealth plane design is a balancing act. The aircraft must be able to avoid detection while also flying fast and far enough, and carrying a big enough payload, to make them militarily useful. They cannot be so expensive that an air force can't actually afford to buy them in meaningful numbers."[39]

In reality, only China and the United States have the capacity and available financial intensity to develop and field stealth technology. By 2007, the last year the CINC data is available, the US maintains a 0.14 value while China has skyrocketed from the Cold War days to have a 0.19 value. Russia, in contrast, has plummeted to a 0.03 value indicative of its lack of ability to utilize its industrial base to develop and employ advanced technologies.[40]

Security

The security of stealth development was an interesting mix of unrestricted sharing, fierce secrecy, and open demonstration. "Stealth had a low profile at first, and was not particularly secret, because nobody knew whether or not it would even be important."[41] The US government's initial investment was through DARPA, which offered small contracts to multiple companies. At Lockheed, the contracts were not even directed to the right division, so Skunk Works almost did not get to participate at all. It was only the intervention of Johnson's successor, Ben Rich, who realized the potential and ensured they could participate in the

[39] "It's Russia's Turn to Learn That Stealth Warplanes Are Hard to Do," accessed March 8, 2017, http://blogs.reuters.com/great-debate/2016/01/20/its-russias-turn-to-learn-that-stealth-warplanes-are-hard-to-do/.
[40] "National Material Capabilities (v4.0) — Correlates of War."
[41] Sweetman, *Lockheed Stealth*, 24.

competition.[42] It was the unclassified nature of the original projects that allowed Lockheed's participation in the first place.

"When Lockheed won the prototype contract in April 1976, the project moved further into the secret world. Like Lockheed's CIA spy planes, it became an unacknowledged special access program (SAP). It is a program whose very existence is one of its core secrets – that is, its military utility would be compromised if its existence was disclosed. After the stealth project was declared an unacknowledged SAP, only those with a clear need-to-know would be told that the project even existed."[43]

As the engineers at Lockheed looked back on the HAVE BLUE program, they reflect that security played a vital role in its success and allowed the US to gain an advantage. Alan Brown, a key designer for engine components is quoted saying "The purpose of secrecy is not just to protect information, but also to deny an adversary the knowledge that a problem has been solved. In the 1970s, most people thought that RCS reduction was not worth doing, because of the fourth-root problem. Nobody's going to put resources into a problem that can't be solved within a generation."[44] Bill Sweetman summarizes the importance succinctly. "Had the United States indicated the levels of RCS that were being achieved, other countries would have pushed stealth much harder."[45]

The US also had to believe that not only were its attempts to keep the projects secret working but that the new capability could actually provide the advantage being sought. "Part of what made stealth an effective strategy for competing with the Soviets was the U.S. intelligence community's confidence in its understanding of Soviet stealth and

[42] Sweetman, *Lockheed Stealth*, 24.
[43] Sweetman, *Lockheed Stealth*, 29.
[44] Sweetman, *Lockheed Stealth*, 29.
[45] Sweetman, *Lockheed Stealth*, 29.

counter-stealth research."[46] In the early years of stealth, the Soviet Union was committed to its air-defense network, which, in-turn, was consistent with long-held policies and doctrine. The Soviets did not focus on conventional capabilities in the early years of the Cold War, preferring a strong nuclear arsenal and large air-defense network. This doctrine followed them through the entirety of the Cold War.[47] Eventually, stealth degraded the Soviet Union's ability to effectively defend its homeland, although that realization occurred at the very end stages of the Cold War.

Beginning in 1991, however, the US started to openly demonstrate its capabilities in a series of conflicts that continue to this day. The US exhibited a new form of air warfare that proved ideal for the ground defenses employed by the Iraqis. "By employing the stealthy F-117, the United States was able to strike at the heart of Iraq before suppressing its air defenses. Indeed, the F-117 was the centerpiece of the strategic air campaign. F-117s attacked with complete surprise and were nearly impervious to Iraqi defenses."[48] From there, the US employed stealth and its new airframes, like the B-2, in conflicts in Yugoslavia, Afghanistan, Iraq (in 2003), and Libya.

This ongoing demonstration produced deep concern in countries that have peer-like capacities. "The new role that air power played in the 1991 Gulf War shattered the Chinese view of air power as primarily an air defense force," causing a shift in their development of capabilities to counter US superiority. [49] A similar change happened in Russia, although it took more time to develop. "The spectacular success of the Western coalition ion the Gulf War proved to be a turning point in the

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[46] Mahnken, *Technology and the American Way of War*, 164.
[47] John W. R. Lepingwell, "Soviet Strategic Air Defense and the Stealth Challenge," *International Security* 14, no. 2 (1989): 67, doi:10.2307/2538855.
[48] Mahnken, *Technology and the American Way of War*, 169.
[49] John Andreas Olsen, ed., *Global Air Power*, 1st ed (Washington, D.C: Potomac Books, 2011), 284.

Soviet Air Force."[50] The collapse of the Soviet Union immediately following the Gulf War delayed Russian air-defense development. As Michael Horowitz would say, 1991 represented an obvious "demonstration point" in which the new stealth technology was revealed to the world.[51]

While continued development in stealth technology by the United States is presumably still classified at SAP levels, the technology is obviously available. Security remains a vital concern for the US to continue its advantage, although competitors are able to gain lessons learned on an almost daily basis. The continued use of stealth capabilities directly leads to the reduction of the US's advantage in this arena. Other capabilities, such as tactics development and counter-counter stealth technologies will allow for the US to maintain some superiority in the near future, but that cannot last forever.

Systemic Integration

While stealth represents a technological advance that helps to change the stakes needed to succeed in both air combat and air defense, it cannot do so by itself. Stealth technology needed to be integrated into a larger system of aerial employment that allowed for planners to utilize its unique capabilities. The advance of stealth technology was paralleled by an advance in precision-guided munitions (PGMs), which first saw employment in the latter years of the Vietnam War.[52] This co-development represented a physical integration of technologies and ensured the US gained a discrete advantage over its adversaries, and presented a deadly effectiveness that was soon demonstrated.

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[50] Olsen, *Global Air Power*, 218.
[51] Michael Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010), 24.
[52] Stephen P. Randolph, *Powerful and Brutal Weapons: Nixon, Kissinger, and the Easter Offensive* (Cambridge, MA: Harvard University Press, 2007), 297.

Operation DESERT STORM provided the perfect example for the US to wield its new capabilities. Possessing both stealth and precision weapons allowed the US to attack on multiple planes early on in the conflict. "As Air Force planners saw it, stealth and precision would allow U.S. forces to engage in 'parallel operations' by attacking targets deep inside Iraq without rolling back Iraqi air defenses or achieving air superiority."[53] This combination yielded excellent results. "Although F-117s flew only 2 percent of the total attack sorties in the war, they struck nearly 40 percent of strategic targets such as the leadership and command and control facilities."[54] This integration proved to be the advantage that either individually would not have achieved to the same level of success.

On the defensive front, new capabilities in support of anti-access strategies are beginning to diminish the advantage held by the stealth-PGM combination. Sam Tangredi quotes a RAND Corporation report in his book about anti-access strategies. "The motives for adopting an anti-access strategy are theoretically compelling: If the U.S. military can arrive in force, it will almost undoubtedly win in a conventional military campaign. A rational opponent should thus seek to acquire the capabilities necessary to disrupt or delay U.S. deployment activities or to deny it the use of regional bases in the hope that, by successfully doing so or threatening to do so, it will prevent or deter the United States from acting."[55] These new anti-access capabilities being developed and employed by countries like China and Russia are specifically designed to deny both the full conventional build-up of forces and the ability of the stealth-PGM combination to act independently of that build-up.

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[53] Mahnken, *Technology and the American Way of War*, 169.
[54] Mahnken, *Technology and the American Way of War*, 169.
[55] Sam J. Tangredi, *Anti-Access Warfare: Countering A2/AD Strategies* (Annapolis, Maryland: Naval Institute Press, 2013), 31.

This is the way of technological advance. Ben Rich sums it up succinctly in his 1994 book: "But schemers never sleep and there are always counters to every new technology. Currently, the French and Germans are trying to create a missile that can shoot down our stealth fighter. It might well take them twenty years to succeed, but ultimately, they will find a way. And then we will find a way to counter their way, and on and on – without an end."[56] Eerily spot-on in his prediction, just over twenty years later, the advantages of stealth are giving way to the counters of other nations. And the US seeks its own counters in return.

Assessment of Advantage

There is no doubt that the US held a significant technological advantage over all of its potential adversaries because of its monopoly on stealth technology. The advantage started in the mid-1980s, even though the US had yet to field an operational combat aircraft. Using multiple sources, including a leading Soviet aerospace engineer, the US was confident that it had achieved a technological lead as early as 1984. "If they have [a stealth] program under way now, it is probably in the very early stages, and deployment probably would not occur until the 1990s."[57] The US publicly released its new stealth fighter as a capability in November 1988, ending nearly a decade of speculation and extraordinary secrecy.[58]

The US first employed its stealth technology in combat in 1989 during Operation JUST CAUSE, the invasion of Panama.[59] While there were not any real air defenses that required stealth technology, it proved the lethal combination of stealth and PGMs. A better test of stealth's capabilities came during Operation DESERT STORM in 1991 where F-117 aircraft proved successful, attacking 31 percent of the first-day

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[56] Rich and Janos, *Skunk Works*, 321.
[57] Mahnken, *Technology and the American Way of War*, 164.
[58] Pace, *Lockheed Skunk Works*, 235.
[59] Sweetman, *Lockheed Stealth*, 59.

targets while representing only 2.5 percent of the overall force.[60] It is here that F-117s earned their well-deserved nickname, "Ghost."[61] Stealth has subsequently been used in nearly every conflict from Bosnia to Kosovo to Afghanistan, Iraq, and even Libya. The advantage has persisted for decades.

The end of the stealth advantage is difficult to quantify. There could be an argument that it ended in March 1999, when the Serbian military was able to shoot down an F-117. There are multiple theories behind the shoot-down, but it is generally accepted that the aircraft was hit by a missile cued by another asset which was coupled with poor tactical mission planning (F-117s had been flying the same routes for days).[62] This incident, by itself, should not be cause to call for the end of the US's stealth advantage. The lessons learned by peer competitors like China and Russia from the Gulf War, however, are another story.

The surge in countering technologies in the post-Gulf War era in both China and Russia will provide the end to the universal advantage held by the United States. Their anti-access capabilities have diminished the ability of US forces to gain uncontested access, using stealth or any other capability. Their strategy, to protect important resources using a layered anti-access layout provides a direct counter to US policy and doctrine that assumes access.[63] These capabilities started to emerge from both China and Russia approximately a decade after Operation DESERT STORM. The Center for Strategic and Budgetary Assessments (CSBA) is one of the prominent think-tanks discussing A2/AD. "CSBA issued its first public papers on anti-access strategies in 2002."[64]

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[60] Sweetman, *Lockheed Stealth*, 62.
[61] Pace, *Lockheed Skunk Works*, 244.
[62] Sweetman, *Lockheed Stealth*, 69.
[63] Tangredi, *Anti-Access Warfare*, 65.
[64] Tangredi, *Anti-Access Warfare*, 49.

2002, then, marks the end of the US's universal advantage. Since then, countering anti-access capabilities has been the focus of US military doctrine and strategy. While stealth can continue to independently provide an advantage against non-peer competitors, it cannot against peers. Stealth as a technology will continue to provide a distinct capability but not a decisive one. Integrated with other technologies, like advanced sensing and avionics, it will likely allow the US to keep a technological edge for at least the foreseeable future but cannot remain the panacea that it represented for nearly twenty years.

Chapter 5

Analysis

This chapter conducts an analysis of the variables explored in the previous case studies. By examining each variable, one can determine the level of impact had on attaining an advantage. This, in turn, provides insight for modern-day strategists to apply these lessons learned to new strategic development. While the conditions and relative context are always subject to change, this analysis affords the opportunity to learn from historical examples, providing empirical data to support current arguments.

First, this chapter analyzes the importance of political context in gaining a competitive advantage. Next, it explores the primacy of a nation's scientific capacity, industrial base, and available resources in providing leverage. Then, it examines the role security plays in the length of the advantage. Subsequently, it analyzes the role of systemic integration and its necessity to gaining the competitive edge. Finally, it assesses the key factors that should be considered by present-day strategists when considering investments in new technology.

Political Context

The pursuit of technological advantages, especially military ones, is inherently a function of international relations and politics. "States are the units whose interactions form the structure of international-political systems."[1] This implies that the political context will be important to the ability to achieve an advantage over competitors. Understanding the political environment allows for greater specification and application of underlying technological achievements. The political context provides the end to be met that allows for the attainment of an advantage.

[1] Kenneth N Waltz, *Theory of International Politics* (United States: Waveland Press, 2010), 95.

Kenneth Waltz, a preeminent scholar in the realist school of international politics, explains the reasons states seek a competitive advantage. "Survival is a prerequisite to achieving any goals that states may have, other than the goal of promoting their own disappearance as political entities."[2] Each state can be different with divergent goals and aspirations, but they all serve a common purpose and act as sovereign political entities.[3] Overall, each state acts in accordance with its own interests, ensuring primarily its survival before promoting other interests.

The structure of the international system can and does change. The cases studied in this thesis demonstrate this point. The interwar period in Europe represented a multipolar system in which both England and Germany had to exist and survive. While the early-warning radar development reduced the context to just those two primary players, they both existed in a more complex world that forced reactions and counter-reactions to others. For example, France was opposed by Britain in its attempt to occupy the Ruhr in 1923 even though Britain and France were bourgeoning allies.[4] Germany had to navigate this complex political environment and make decisions that would ultimately serve her best interests.

The development of atomic weapons happened during a shift to a bipolar political environment in the immediate aftermath of World War II. This new world order was characterized by both the material competition of the nuclear arms race as well as the ideological competition between the Soviet Union's authoritarian and the U.S.'s democratic systems. Both sides of the competition clearly understood the stakes and sought

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[2] Waltz, *Theory of International Politics*, 92.
[3] Waltz, *Theory of International Politics*, 96.
[4] Eberhard Jäckel, *Hitler's World View: A Blueprint for Power* (Cambridge, MA: Harvard University Press, 1981), 31.

to achieve an advantage throughout the Cold War.[5] The perceptions on both sides informed decision making and investment decisions. Robert Jervis summarizes this by saying that "the world is tightly interconnected. What happens in one interaction influences other outcomes as each state scrutinizes the others' behavior for indications of interests, strengths, and weaknesses."[6] While the bipolar world was seemingly less complex than the multipolar world that preceded it, there was still a need to understand how actions and reactions could impact the overall state of the international community.

The end of the Cold War brought yet another shift in the structure of the international political system. The initial benefits of stealth technology sought to counter the threat posed by the Soviet Union's considerable air-defense capability. The collapse of the Soviet Union presented the opportunity for the U.S. to achieve a global advantage that could not be countered by any other state for over a decade. In many respects, though, the collapse of the bipolar environment made for a less stable international structure. Local conflicts that had generally been kept in check by the overarching competition between the U.S. and Soviet Union now had the opportunity to flare up.[7] This allowed the U.S. to employ its most-advanced technology against lower-tier competitors like Iraq, Serbia, and others who had no capability to counter such capabilities.

Political context matters in technological development. For early-warning radar development, the differences between relationships and the relative political isolation of Germany compared to the British/French friendliness present a stark contrast that informed

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[5] Michael Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010), 125.
[6] Robert Jervis, *Perception and Misperception in International Politics*, 13th ed. (United States: Princeton University Press, 1976), 61.
[7] Benjamin S. Lambeth, *The Transformation of American Air Power*, Cornell Studies in Security Affairs (Ithaca, NY: Cornell University Press, 2000), 153.

strategic decision-making.[8] The stability of the bipolar post-WWII environment afforded both the U.S. and the Soviet Union the ability to focus exclusively on each other's actions, resulting in the long-term nuclear arms race that characterized the Cold War era. The relative instability of the post-Cold War period when the U.S. remained the sole superpower resulted in an increased operations tempo and a reliance on technologies designed for the bipolar environment. This also explains the slow reaction to developing anti-access capabilities and a search for new technological advantages. All of these cases demonstrate the importance of the political context in technological development.

Scientific Capacity/Industrial Base/Resources

The capacity of a state's scientific, industrial, and resource base represents a key factor in determining its ability to gain a technological advantage over its competitors. Richard Heilbroner tells us that "the steady expansion of scientific research, dedicated to the exploration of nature's secrets and to their harnessing for social use, provided an increasingly important stimulus for technological advance from the middle of the nineteenth century."[9] A nation's ability to innovate is largely dependent on its scientific base. Its ability to exploit the innovations, however, is wholly dependent on its industrial base and available resources. This combination is pivotal to a nation's ability to achieve advantage.

Stephen Rosen considers the impact of the scientific community in his book, *Winning the Next War: Innovation and the Modern Military*. In it, he recognizes the importance of civilian and military scientists in furthering technological capabilities. He also understands the complexity of the military technology environment. "Military research

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[8] Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*, Cornell studies in security affairs (Ithaca: Cornell University Press, 1984), 41.

[9] Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?: The Dilemma of Technological Determinism* (Cambridge, MA: MIT Press, 1994), 64.

and development decisions are made amid great uncertainties."[10] Civilian scientists participated in the research and development process since at least World War I. This integration ensures military access to additional capabilities and research. In some cases, civilians are given decision-making authority, but there seems to be little evidence that their decisions are any better than military senior leaders.[11] Ultimately, scientific development in the military arena has to allow for achievement of political objectives.

The innovative nature of science provides the underlying research-and-development capability, but a nation must then be able to exploit that capability to achieve an advantage. The Composite Index of National Capability (CINC) data used throughout this study provides relative potential between states.[12] From the data presented, it appears that the relative parity between states will indicate the likelihood of a competition in the technological realm. Where the states have relatively equal capabilities, they will seek to minimize adversary advantages. For example, the relative parity between Britain and Germany in the 1930s and again between the US and Soviet Union in the 1960s led to a stiff competition between the states. The vast difference in capability between Iraq and the US in 1990 meant that Iraq had no chance of competing technologically, which is an obvious conclusion.

For significant technological competition to occur, it seems that states likely need to be great powers. John Mearsheimer explains how to identify great powers. "Great powers are determined largely on the basis of their relative military capability. To qualify as a great power, a state must have sufficient military assets to put up a serious fight in an all-out

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[10] Stephen Peter Rosen, *Winning the next War: Innovation and the Modern Military*, Cornell Studies in Security Affairs (Ithaca: Cornell Univ. Press, 1991), 221.
[11] Rosen, *Winning the next War*, 237–50.
[12] Stephen D. Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, N.J.: Princeton University Press, 2004), 21.

conventional war against the most powerful state in the world."[13] This hypothesis is confirmed by the CINC data throughout this thesis in that those states with significant military power have the ability to produce advanced technological capabilities. Once a state produces them or proves the capability to do so, it can seek an advantage over its potential adversaries in pursuit of its individual interests. Additionally, this confirms Michael Horowitz's requirement that states in pursuit of new technological innovations must ensure they invest enough financial intensity in the endeavor.[14]

Security

Security plays an important role in the ability of a state to gain and maintain an advantage. During the development process, states use whatever capabilities they can manage to gain insight into the actions of competitors. Use of techniques like espionage and surveillance is crucial to a state's ability to maintain parity with its adversaries. The basis of the security dilemma is founded in this vein. "Arms produced to defend can usually be used to attack," so a state must ensure it understands the capabilities of its competitors to guarantee its ability to maintain its basic interests.[15]

To be useful, innovations have to be demonstrated. Once this demonstration point occurs, then all actors have the knowledge that the technology is at least feasible. Shortening this timeline is the goal for an opposing actor, while the opposite is true for the innovator. For example, the British laced tight security on the Chain Home system for even their own operators, ensuring the Germans were unable to detect the importance of the system to Britain's defensive strategy. This secrecy effort was successful, as even the Luftwaffe intelligence chief never

[13] John J. Mearsheimer, *The Tragedy of Great Power Politics*, Updated (New York, NY, United States: WW Norton & Co, 2014), 5.
[14] Horowitz, *The Diffusion of Military Power*, 30–31.
[15] Jervis, *Perception and Misperception in International Politics*, 64.

mentioned the existence of the system as a threat leading into the Battle of Britain.[16] This lengthened the advantage the British were able to achieve over the Germans in the early years of World War II.

In contrast to the British success is the infiltration of Soviet spies into the Manhattan Project. The presence of Soviet agents and their success at getting information back to the Soviet Union considerably shortened the timeline needed to produce similar results. With at least two years advance notice on the potential for Plutonium-based weapons, courtesy of Klaus Fuchs the Soviets were able to demonstrate their own weapon by 1949 even though American senior leaders expected a much longer-term advantage.[17]

One of the underlying issues with technological innovation, however, is the ability to do so organically. The Soviet Union's espionage efforts in the Cold War provided them an ability to reduce organic research-and-development timelines. By stealing Western technology, the Soviets were able to lessen their investment in research and divert resources to other projects.[18] This, however, caused problems with their ability to innovate. The Central Intelligence Agency concluded, "in spite of the several decades of massive investing in indigenous R&D, the prospects are small that the Soviets can reduce their dependence on a large variety of Western products and technology in this decade and the next without allowing the technological gap to widen. The main reasons for this continuing need are endemic to the Soviet system: the lack of adequate incentives, inflexible bureaucratic structures, excessive

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[16] Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York, NY: Simon & Schuster, 1996), 92.
[17] Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1996), 211.
[18] *Soviet Acquisition of Militarily Significant Western Technology: An Update* (Central Intelligence Agency, September 1985), 8, http://www.dtic.mil/dtic/tr/fulltext/u2/a160564.pdf.

secrecy, and insularity from the West."[19] Their system was "optimized for imitation rather than innovation."[20]

Stealth technology helps prove the success of security in technological innovation. Even though the original products were unclassified, once a military capability was determined to be possible, the strictest classifications were established. The Special Access Program classification on all stealth developments ensured a strict secrecy within the U.S. As mentioned by Alan Brown in Chapter 4, "the purpose of secrecy is not just to protect information, but also to deny an adversary the knowledge that a problem has been solved."[21] This secrecy guaranteed the U.S. an advantage up until it publicly demonstrated stealth technology in 1991. By then, other factors, including the political collapse of the Soviet Union allowed for the advantage to last for twenty years.

Systemic Integration

Horowitz's complement to financial intensity is organizational capital. This concept identifies the willingness or ability of an organization to adapt to a new technology.[22] This represents a key component to systemic integration because an organization is forced to either integrate a new technology into existing processes or create new processes altogether. This was said succinctly by famous military strategist, Julian Corbett. "Limited wars do not turn upon the armed strength of the belligerents, but upon the amount of that strength which they are able or willing to bring to bear at the decisive point."[23] The

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[19] *Soviet Acquisition of Militarily Significant Western Technology: An Update*, 1.
[20] Jon R. Lindsay, Tai Ming Cheung, and Derek S. Reveron, eds., *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain* (New York: Oxford University Press, 2015), 79.
[21] Bill Sweetman, *Lockheed Stealth* (St. Paul, MN: MBI Pub. Co., 2001), 29.
[22] Horowitz, *The Diffusion of Military Power*, 10.
[23] Sir Julian Stafford Corbett, *Some Principles of Maritime Strategy* (New York, NY, United States: Naval Institute Press, 1988), 58.

willingness to integrate new technologies is determinant in the ability to gain a technological advantage over adversaries.

Systemic integration appears to be decisive in two of the three cases studied. This is amalgamation of capability and strategy that produces advantage over competitors. In both the radar and stealth studies, integration was a critical variable that produced an advantage for Britain and the U.S., respectively. This is primarily because the technology helped achieve a specific political end.

For Britain, the creation of the Dowding system incorporating radar technology with fighter development and a command-and-control system provided the edge. This system was the product of intellectual integration that was focused on achieving the British political end: avoiding air attacks like those seen during WWI. The Germans held the scientific and industrial advantage, but they did not have an objective upon which to focus their efforts. This led to a sporadic employment of radar capabilities on their own part and a lack of recognition of British developments using radar technology. Ultimately, the Germans suffered considerable losses due to the British advantage in this technological realm.

For the U.S., stealth afforded an advantage in two different ways. First, stealth was designed to counter a specific Soviet capability, its comprehensive air-defense system, components of which proved so deadly to U.S. forces during the Vietnam War. The problem with this assessment, however, is that the U.S. never tested its new technology against the Soviets, so the perceived advantage is merely speculative. Secondly, the U.S. physically integrated new technologies by pairing stealth technology with precision-guided munitions, affording the ability to execute "parallel operations." This physical integration led to the intellectual reinvigoration of the concept of strategic conventional

bombing.[24] Stealth gave the U.S. an advantage over both the peer-competitor Soviets, and all other countries after the Soviet Union's collapse.

Why was systemic integration not as important in atomic weapons development? The easiest answer is that the bipolar competition between the US and Soviet Union did not leave much room for either to achieve a technological advantage. Both countries integrated nuclear capabilities in their national strategies, which forced creation of new processes within each government. Both countries completely invested in nuclear strategy, ensuring that neither side could achieve an advantage. In a sense, the systemic integration was so complete that it infiltrated every level, from military to political, ensuring continued parity.

Assessment

All of the variables studied throughout this thesis have an impact on a nation's ability to gain a technological advantage over a competitor. Two of them, however, stand out above the others. The first is systemic integration, which includes a requirement for a developed strategy. The second is an unstable political context. With both of these conditions met, states are able to pursue technological innovations with the expectation that it may yield an advantage.

Integrating technologies into strategies is probably the single most important component to seeking an advantage. As Thomas Mahnken states, "technology is only as effective as the strategy is serves."[25] In some cases, as in the stealth case, physical integration can lead to redevelopment of old strategies that will serve the political purpose. In other cases, as in the British employment of early-warning radar, intellectual integration of technologies with the desired end is effective on

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[24] Thomas G. Mahnken, *Technology and the American Way of War* (New York: Columbia University Press, 2008), 169.
[25] Mahnken, *Technology and the American Way of War*, 227.

its own. In his aptly named work, *The Strategy Bridge*, modern-day strategist Colin Gray says "strategy functions as the only purpose-built bridge connecting political ends with the methods and means for their attempted achievement."[26] Focused innovation provides the path to advantage, connecting the possible means via innovation with the political ends – strategy does the connection and is imperative to achieving a successful advantage.

The second key component is an unstable political environment. Waltz defines a bipolar world as the most stable as third parties cannot easily disrupt the balance of power.[27] In multipolar worlds, interdependence is more prevalent and causes instability amongst nations. This instability could be either from a direct outside threat or from a focus away from the power attempting to gain an advantage, as in the case of Germany in the 1930s. While Waltz does not specifically mention the possibility of a unipolar environment, the post-Cold War environment certainly looked like one. The relative instability, especially when compared to the Cold War stability, demonstrates that the bipolar environment is truly more stable. During the Cold War, neither the U.S. nor the Soviet Union had much success in achieving a technological advantage. During the post-Cold War era, the U.S. was able to achieve an advantage mainly due to the vast disparity between it and its competitors. That ability is starting to swing as a peer competitor emerges.

Scientific capacity, industrial base, and available resources are ranked lower in impact primarily because they have to be assumed to be present in order for a technological advantage to be achieved. The CINC data provided throughout this thesis shows that states that have near

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[26] Colin S Gray, *The Strategy Bridge: Theory for Practice* (Oxford: Oxford University Press, 2010), 238.
[27] Waltz, *Theory of International Politics*, 145.

parity can compete in the technological arena. States with disparate CINC values will always cede the technological edge.

Security is also ranked lower on the priority list. The ability to secure the advantage can provide only a slightly increased duration. States will go to great lengths through espionage and surveillance to shorten any ability to gain an advantage by a competitor. Once a new technology is demonstrated, however, a way to counter it will most certainly be pursued. These counters range from developing similar technologies to creating low-cost protection capabilities that negate the perceived benefits of employing the new technologies. In this sense, security is only valuable in the short-term in an environment where a state is functionally capable of competing in the technological realm.

Systemic integration in an unstable political context provides the best opportunity to achieve technological advantage. The length of an advantage depends primarily on the capability of an adversary to match technological skill. In a bipolar world, advantages cannot be expected to last for a long period. In a multipolar world, advantages last only until they are used against a specific competitor. In a unipolar world, advantages will last only as long as the competitors are unable to match or counter the capability. Technological advantages are wholly dependent on the context in which they are expected to be employed.

Chapter 6

Conclusions

The pursuit of technological advantage provides a state the opportunity to maintain or shift the balance of power in its favor. This has been especially true since the explosion of science-based technologies in the world since the industrial revolution. Merritt Smith tells us that beginning with the late nineteenth century, writers viewed "new technologies both as instruments of power and as triumphant symbols of human progress."[1] The cases analyzed in this thesis represent just a few of the technological advances of the twentieth century, but they are representative of the whole of technological innovation. The underlying question throughout was about how long advantages lasted once achieved. Chapter 5 provides the wholly unsatisfying answer: it depends. The international environment is complicated and the context is vital to understanding the length of any attained advantage.

This chapter seeks to find application of this analysis for the twenty-first century. The 2014 initiation of the third-offset strategy by then Secretary of Defense Chuck Hagel demonstrates that the U.S. still believes that it can and must achieve technological advantages to maintain its position in the international order. Competitors, especially peer or near-peer competitors like China and Russia, are countering the technological advantage owned by the U.S. in order to minimize U.S. influence and shift the balance of power in their favor. First, this chapter examines the advent of anti-access/area-denial (A2/AD) strategies used to counter US advantages. Next, it briefly explores the development of the virtual domain and strategies to achieve advantages in that realm.

[1] Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?: The Dilemma of Technological Determinism* (Cambridge, MA: MIT Press, 1994), 8.

Finally, this chapter discusses the importance of integrated strategies and the role technology helps to play in achieving them.

Advent of A2/AD Strategies

The political environment at the end of the second decade of the twenty-first century is in a state of flux. The seemingly stable world inherited by the United States after the collapse of the Soviet Union was not as steady as it first appeared. The position of the US as the sole superpower forced engagements in a multitude of conflicts that it likely would have avoided during the Cold War. This diverted focus from maintaining its position relative to potential great powers to accomplishing limited objectives in localized conflicts ranging from Yugoslavia to the continuing conflicts in Iraq, Afghanistan, and Syria. This diversion also allowed those potential great-power competitors, like China and a resurgent Russia, to achieve capabilities that could threaten the global balance of power by reducing US advantage in the physical realm. These are primarily accomplished through A2/AD capabilities that counter US assumptions of being able to achieve military success anywhere in the world.

Anti-access warfare is a seductive strategy. Denying American access impedes its ability to achieve objectives. Sam Tangredi comes to an obvious conclusion when he says "if the US military can arrive in force, it will almost undoubtedly win in a conventional military campaign. A rational opponent should seek to disrupt or delay US deployment to prevent or deter the US from acting."[2] The proliferation of these anti-access strategies, and the technological capabilities needed to enable them presents a significant danger to US power projection across the globe. Anti-access capabilities can be defeated, but this generally requires the expenditure of resources at a level that changes the cost-

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[2] Sam J. Tangredi, *Anti-Access Warfare: Countering A2/AD Strategies* (Annapolis, Maryland: Naval Institute Press, 2013), 31.

benefit calculation, even for a great power with seemingly unlimited resources.

Anti-access strategies employed by competitors force a shift in American strategic thinking. Tangredi "emphasizes anti-access warfare as part of a grand strategy in the belief that without applying the other elements of power – political, economic, diplomatic, and so-called soft power – you cannot effectively defeat robust *military* anti-access networks except at great cost."[3] The implication is that the reliance on a single military source to project the complement of American power will no longer be sufficient in the face of anti-access strategies. The US will be forced to think strategically, beyond just the military capabilities it is used to employing, to counter competition in the new century.

Application to the Virtual Domain

The cases studied in the previous chapters are limited to the post-industrial revolution era and reside exclusively in the physical domain. The digital revolution at the end of the twentieth century transformed the overall environment much the same way the industrial revolution changed the environment in the mid-nineteenth century.[4] It also opened new avenues of approach to achieving advantage. The concept of information warfare is relatively new and will be a predominant player in technological advantage for the coming decades. "Information warfare is the use and management of information technology to pursue a competitive advantage over an opponent."[5] This affords new domains for adversaries to contest, forcing new investments to maintain an advantage.

[3] Tangredi, *Anti-Access Warfare*, 239.
[4] "What Is the Digital Revolution? - Definition from Techopedia," *Techopedia.com*, accessed March 24, 2017, https://www.techopedia.com/definition/23371/digital-revolution.
[5] Gabriel Weimann, *Terrorism in Cyberspace: The next Generation* (Washington, D.C. : New York : Columbia University Press: Woodrow Wilson Center Press, 2015), 186.

The question becomes whether the variables that were important in industrial-age advantages remain so in the information age. In China's efforts to counter US physical capabilities, it seemed to rely specifically on physical counters. China invested heavily on corporate and industrial espionage to enable development of counters to US technological capabilities. In that sense, it followed the path the Soviets did towards the end of the Cold War. In doing so, it shortens timelines to imitate Western technology but lacks indigenous efforts to innovate on its own.[6] Scholars Jon Lindsay and Tai Ming Cheung offer that "if China is to become the first-rate S&T power it aspires to be, it will have to perform on a level playing field without recourse to illicit technology."[7]

In the cyber realm, the investment requirements in science, industrial base, and resources tend to fade away. The proliferation of cyber capabilities for even non-state actors make this domain especially troublesome. "It's not just that the ideas behind the [cyber] weapons spread globally in mere microseconds, but that the required tools to turn a blueprint into action do not require the kind of large-scale human, financial, or physical resources one used to need."[8] For China, this helps its efforts in pursuit of its *shahoujian* strategy which tries to help its perceived technological inferiority prevail over the US.[9] The constraints present in the twentieth century needed to gain a technological advantage may not be present in the twenty-first. This also adds additional complexity to the environment.

[6] Jon R. Lindsay, Tai Ming Cheung, and Derek S. Reveron, eds., *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain* (New York: Oxford University Press, 2015), 78–79.
[7] Lindsay, Cheung, and Reveron, *China and Cybersecurity*, 79–80.
[8] P. W. Singer, *Cybersecurity and Cyberwar: What Everyone Needs to Know* (Oxford; New York: Oxford University Press, 2014), 159.
[9] Jeff Reilly, "Multidomain Operations: A Subtle but Significant Transition in Military Thought," *Air and Space Power Journal* 30, no. 1 (Spring 2016): 66.

Role of Strategy

As mentioned in the final assessment in chapter 5, strategy played a key role in gaining technological advantages in the twentieth century, and will continue to do so for the foreseeable future. Strategy provides the necessary adhesive to bridge the gap between ideas, capabilities, and utility. The political context is complex and decision-makers will need to be explicit in stating their goals. Once their "ends" are established, strategists can then employ available means, or develop new means that help to achieve the ends.

The complexity of the environment, however, requires the exercise of caution. There is a tendency to employ technologies to meet the current ends desired, which works in that specific event but then people tend to rely on those tried-and-true solutions. Paradoxically, this opens up the policy or strategy to defeat. From a military perspective, this often looks like matching up new technologies with currently accepted policies. Barry Posen says that "a state will go to great lengths to reconcile technology with their preferred doctrine."[10] J.F.C. Fuller offers a prescient warning about the consequences of doctrine. "The danger of doctrine is that it is apt to ossify into dogma."[11] Once dogma takes over, it is difficult to find new or innovative solutions, regardless of available capabilities.

Colin Gray defines strategy as "the direction and use made of means by chosen ways in order to achieve desired ends."[12] Strategists must be willing to be flexible and respond to the ever-changing environment. As the pace of change quickens, as in the current

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[10] Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*, Cornell studies in security affairs (Ithaca: Cornell University Press, 1984), 67.
[11] J F C Fuller, *The Foundations of the Science of War* (London, United Kingdom: Books Express Publishing, 2012), 254.
[12] Colin S Gray, *The Strategy Bridge: Theory for Practice* (Oxford: Oxford University Press, 2010), 18.

information age as compared to the industrial age, the ability to respond and innovate must change with it. Everett Dolman examines the role firm doctrine plays in strategy's demise. "Doctrine and dogma are the foundations of tactics, and if allowed to determine it, the ruin of strategy."[13] This is seemingly a simple task, but it is critically difficult. Strategy is the art of advantage, technological or otherwise.

Final Thoughts

The currently proposed "third-offset" strategy provides a way-forward for American warfighting that is rooted in the past. With peer competitors like China and Russia, which are capable of developing or matching new technological developments, expected advantages dependent on exquisite technology cannot be expected to yield long-duration advantages. This is already becoming clear as the advantages of stealth are yielding to anti-access strategies of capable competitors seeking to deny US influence. It is imperative for US strategists to consider the consequences and costs of new-technology development before committing to a new strategy that will not achieve the long-term goals sought.

Ultimately, the ability for a country to achieve a technological advantage depends on which potential adversary is being targeted. In the modern world, where Deputy Defense Secretary Robert Work calls China and Russia "pacing competitors, because they are developing advanced capabilities that are potentially threatening to us," the ability of the US to do so should be questioned.[14] Short-term advantages, like those seen in the Battle of Britain, can be achieved through intellectual integration, which can be sufficient to gain desired strategic results. The

[13] Everett Carl Dolman, *Pure Strategy: Power and Principle in the Space and Information Age* (London: Frank Cass, 2007), 193.

[14] Cheryl Pellerin, "Deputy Secretary: Third Offset Strategy Bolsters America's Military Deterrence," *U.S. DEPARTMENT OF DEFENSE*, October 31, 2016, https://www.defense.gov/News/Article/Article/991434/deputy-secretary-third-offset-strategy-bolsters-americas-military-deterrence.

time for reliance on exquisite technologies to provide the edge needed to defeat adversaries may indeed be past.

Bibliography

Articles

"Chinese Stealth Fighter Plans Revealed." *New Scientist*. Accessed March 8, 2017. https://www.newscientist.com/article/dn3174-chinese-stealth-fighter-plans-revealed/.

"It's Russia's Turn to Learn That Stealth Warplanes Are Hard to Do." Accessed March 8, 2017. http://blogs.reuters.com/great-debate/2016/01/20/its-russias-turn-to-learn-that-stealth-warplanes-are-hard-to-do/.

Jones, Steve. "How Did US Foreign Policy Change after 9/11?" *ThoughtCo*. Accessed March 8, 2017. https://www.thoughtco.com/us-foreign-policy-after-9-11-3310293.

Lepingwell, John W. R. "Soviet Strategic Air Defense and the Stealth Challenge." *International Security* 14, no. 2 (1989): 64–100. doi:10.2307/2538855.

Pellerin, Cheryl. "Deputy Secretary: Third Offset Strategy Bolsters America's Military Deterrence." *U.S. DEPARTMENT OF DEFENSE*, October 31, 2016, https://www.defense.gov/News/Article/Article/991434/deputy-secretary-third-offset-strategy-bolsters-americas-military-deterrence.

"Pentagon Can't Afford To Field 3rd Offset Tech Under BCA: Frank Kendall « Breaking Defense - Defense Industry News, Analysis and Commentary." Accessed January 29, 2017. http://breakingdefense.com/2016/10/pentagon-cant-afford-to-field-3rd-offset-tech-frank-kendall/.

Reilly, Jeff. "Multidomain Operations: A Subtle but Significant Transition in Military Thought." *Air and Space Power Journal* 30, no. 1 (Spring 2016): 61–73.

Reynolds, David. *Long Shadow: The Legacies of the Great War in the Twentieth Century*, 2015. https://www.overdrive.com/search?q=EF1AB17B-DCA7-486A-9F2F-E43548CB0B21.

Simón, Luis. "The 'Third' US Offset Strategy and Europe's 'Anti-Access' Challenge." *Journal of Strategic Studies* 39, no. 3 (April 15, 2016): 417–45. doi:10.1080/01402390.2016.1163260.

"Stealthier Stealth? Seventh Upgraded Chinese Stealth Fighter Prototype Aims to Take Flight." *Popular Science*. Accessed March 8, 2017. http://www.popsci.com/stealthier-stealth-seventh-upgraded-chinese-stealth-fighter-prototype-aims-to-take-flight.

"What Is the Digital Revolution? - Definition from Techopedia." *Techopedia.com*. Accessed March 24, 2017. https://www.techopedia.com/definition/23371/digital-revolution.
"What Is the Third Offset Strategy? | RealClearDefense." Accessed January 29, 2017. http://www.realcleardefense.com/articles/2016/02/16/what_is_the_third_offset_strategy_109034.html.

Books

Baggott, Jim. *The First War of Physics: The Secret History of the Atomic Bomb, 1939-1949*. New York: Pegasus Books, 2010.
Biddle, Stephen D. *Military Power: Explaining Victory and Defeat in Modern Battle*. Princeton, NJ: Princeton University Press, 2004.
Brown, Anthony Cave, Charles Brown MacDonald, and United States, eds. *The Secret History of the Atomic Bomb*. New York: Dial Press, 1977.
Buderi, Robert. *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*. New York, NY: Simon & Schuster, 1996.
Bungay, Stephen. *The Most Dangerous Enemy: A History of the Battle of Britain*. United Kingdom: Aurum Press, 2015.
Corbett, Sir Julian Stafford. *Some Principles of Maritime Strategy*. New York, NY, United States: Naval Institute Press, 1988.
Craig, Campbell. *Destroying the Village: Eisenhower and Thermonuclear War*. New York: Columbia University Press, 1998.
Dolman, Everett Carl. *Pure Strategy: Power and Principle in the Space and Information Age*. London: Frank Cass, 2007.
Edgerton, David. *Britain's War Machine: Weapons, Resources, and Experts in the Second World War*. Oxford University Press, 2011. https://books.google.com/books?id=IKZC256tZ0IC.
Fuller, J F C. *The Foundations of the Science of War*. London, United Kingdom: Books Express Publishing, 2012.
Galati, Gaspare. *100 Years of Radar*. Cham: Springer, 2016.
Gilpin, Robert. *War and Change in World Politics*. Cambridge: Cambridge University Press, 1983.
Gray, Colin S. *The Strategy Bridge: Theory for Practice*. Oxford: Oxford University Press, 2010.
Horowitz, Michael. *The Diffusion of Military Power: Causes and Consequences for International Politics*. Princeton, N.J: Princeton University Press, 2010.
Hugill, Peter J. *Global Communications Since 1844: Geopolitics and Technology*. Baltimore, MD: Johns Hopkins University Press, 1999.
Iriye, A., and P. Saunier. *The Palgrave Dictionary of Transnational History: From the Mid-19th Century to the Present Day*. Palgrave

Macmillan Transnational History Series. Palgrave Macmillan UK, 2016. https://books.google.com/books?id=bKAYDAAAQBAJ.
Jäckel, Eberhard. *Hitler's World View: A Blueprint for Power*. Cambridge, MA: Harvard University Press, 1981.
Jervis, Robert. *Perception and Misperception in International Politics*. 13th ed. United States: Princeton University Press, 1976.
Kitfield, James. *Prodigal Soldiers*. Brassey's paperback ed. An AUSA Institute of Land Warfare Book. Washington, DC: Brassey's, 1997.
Lambeth, Benjamin S. *The Transformation of American Air Power*. Cornell Studies in Security Affairs. Ithaca, NY: Cornell University Press, 2000.
Latham, Colin, Anne Stobbs, and Edward Fennessy. *Radar: A Wartime Miracle*. Oxford, United Kingdom: History Press Limited, 1996.
Lindsay, Jon R., Tai Ming Cheung, and Derek S. Reveron, eds. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*. New York: Oxford University Press, 2015.
MacKenzie, Donald A. *Inventing accuracy: a historical sociology of nuclear missile guidance*. 4. pr. Cambridge, Mass.: MIT Press, 2001.
Mahnken, Thomas G. *Technology and the American Way of War*. New York: Columbia University Press, 2008.
Maiolo, Joseph A, and King's College London. *The Royal Navy and Nazi Germany, 1933-39: A Study in Appeasement and the Origins of the Second World War*. London: Macmillan, 1998. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=492428.
Mearsheimer, John J. *The Tragedy of Great Power Politics*. Updated. New York, NY, United States: WW Norton & Co, 2014.
Neilson, Keith, Greg Kennedy, and David French, eds. *The British Way in Warfare: Power and the International System, 1856-1956: Essays in Honour of David French*. Farnham, England; Burlington, VT: Ashgate, 2010.
Olsen, John Andreas, ed. *Global Air Power*. 1st ed. Washington, D.C: Potomac Books, 2011.
Oppenheimer, J. Robert, Alice Kimball Smith, and Charles Weiner. *Robert Oppenheimer, Letters and Recollections*. Cambridge, MA: Harvard University Press, 1980.
Ostry, Sylvia, and Richard R. Nelson. *Techno-Nationalism and Techno-Globalism: Conflict and Cooperation*. Integrating National Economies. Washington, DC: Brookings Institution, 1995.
Pace, Steve. *Lockheed Skunk Works*. Osceola, WI: Motorbooks International, 1992.
Peebles, Curtis. *Dark Eagles: A History of Top Secret U.S. Aircraft Programs*. Novato, CA: Presidio, 1995.

Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Cornell studies in security affairs. Ithaca: Cornell Univ.Pr, 1984.
Pritchard, David, and R V Jones. *The Radar War: Germany's Pioneering Achievement, 1904-45*. Aldershot, England: HarperCollins Publishers, 1989.
Randolph, Stephen P. *Powerful and Brutal Weapons: Nixon, Kissinger, and the Easter Offensive*. Cambridge, Mass: Harvard University Press, 2007.
Rhodes, Richard. *Dark Sun: The Making of the Hydrogen Bomb*. New York: Simon & Schuster, 1996.
Rich, Ben R., and Leo Janos. *Skunk Works: A Personal Memoir of My Years at Lockheed*. 1st ed. Boston: Little, Brown, 1994.
Rosen, Stephen Peter. *Winning the next War: Innovation and the Modern Military*. Cornell Studies in Security Affairs. Ithaca: Cornell Univ. Press, 1991.
Sakharov, Andreĭ. *Memoirs*. 1st Vintage Books ed. New York: Vintage Books, 1992.
Singer, P. W. *Cybersecurity and Cyberwar: What Everyone Needs to Know*. Oxford ; New York: Oxford University Press, 2014.
Smith, Merritt Roe, and Leo Marx, eds. *Does Technology Drive History?: The Dilemma of Technological Determinism*. Cambridge, Mass: MIT Press, 1994.
Sweetman, Bill. *Lockheed Stealth*. St. Paul, MN: MBI Pub. Co., 2001.
Tangredi, Sam J. *Anti-Access Warfare: Countering A2/AD Strategies*. Annapolis, Maryland: Naval Institute Press, 2013.
Tooze, Adam. *The Wages of Destruction: The Making and Breaking of the Nazi Economy*. New York: Penguin (Non-Classics), 2008.
Ufimtsev, Pyotr. *Method of Edge Waves in the Physical Theory of Diffraction*. Technical Report. Wright Patterson AFB, OH: National Air Intelligence Center, 1971.
Waltz, Kenneth N. *Theory of International Politics*. United States: Waveland Press, 2010.
Weimann, Gabriel. *Terrorism in Cyberspace: The next Generation*. Washington, D.C. : New York : Columbia University Press: Woodrow Wilson Center Press, 2015.
Zhu, Feng. *China's Ascent: Power, Security, and the Future of International Politics*. Edited by Robert S. Ross, Zhu Feng, and Susan Leigh Star. United States: Cornell University Press, 2008.

Reports

Manyin, Mark E., Stephen Daggett, Ben Dolven, Susan V. Lawrence, Michael F. Martin, Ronald O'Rourke, and Bruce Vaugn. *Pivot to the Pacific? The Obama Administration's "Rebalancing" Toward Asia.*

CRS Report for Congress. Washington, D.C: Congressional Research Service, March 28, 2012. https://fas.org/sgp/crs/natsec/R42448.pdf.
Soviet Acquisition of Militarily Significant Western Technology: An Update. Central Intelligence Agency, September 1985. http://www.dtic.mil/dtic/tr/fulltext/u2/a160564.pdf.

Speeches

"George Bush: Address Before a Joint Session of the Congress on the State of the Union." Accessed March 8, 2017. http://www.presidency.ucsb.edu/ws/?pid=19253.

Webpages

"National Material Capabilities (v4.0) — Correlates of War." Folder. Accessed January 30, 2017. http://www.correlatesofwar.org/data-sets/national-material-capabilities.
"Nuclear Notebook." *Bulletin of the Atomic Scientists*. Accessed February 1, 2017. http://thebulletin.org/nuclear-notebook-multimedia.
"Radar." Accessed January 3, 2017. http://www.ece.umd.edu/~taylor/Electrons6.htm.